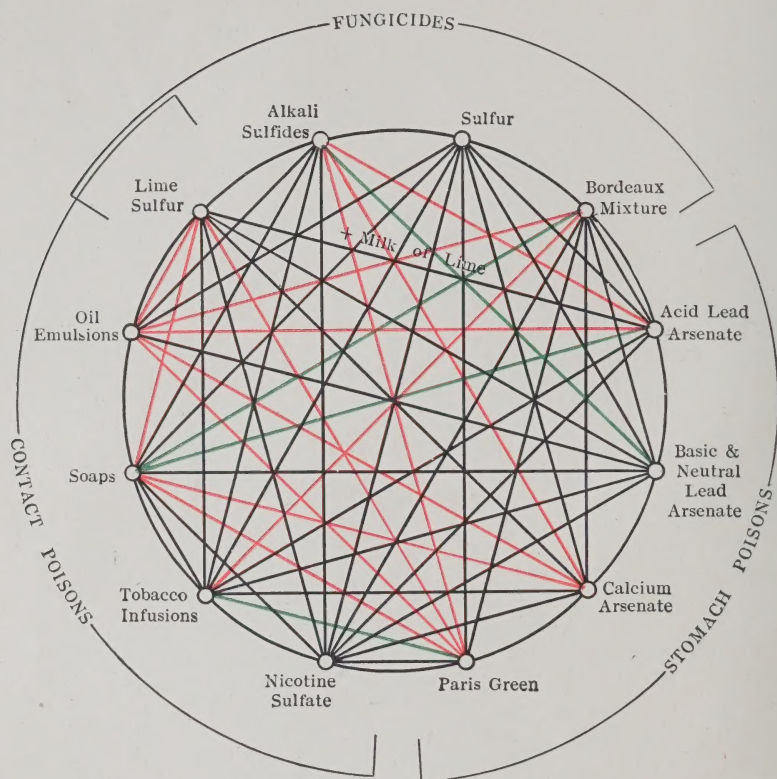




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SPRAY COMPATIBILITY CHART



KEY TO CHART

- Safe Combinations
- Doubtful Combinations, sometimes useful
- Dangerous Combinations

Adapted from Cal. Exp. Sta. Cir. No. 195.

FIG. 1.

(Frontispiece)

INSECTICIDES AND FUNGICIDES SPRAYING AND DUSTING EQUIPMENT

*A Laboratory Manual with
Supplementary Text Material*

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THE AUTHORS.

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PLAN AND PURPOSE OF THIS MANUAL

THIS manual is designed to offer instruction in the preparation of insecticides and fungicides; the construction, selection, testing and operation of spraying and dusting equipment. The literature on this subject is available in vast quantities and in great detail; no recent effort has been made, however, to gather together information along this line in the form of a textbook, nor has any laboratory manual relating to the subject been prepared for general distribution in recent years, although it is a subject of vital importance to those who are in any way connected with the production of horticultural plants.

Take the orchard as an example: a man may neglect pruning, may supply an insufficient amount of food and water, and fall short in other phases of orchard management, without suffering the final loss, in any single instance, which is incurred by neglecting proper control measures for the pests which abound in the orchard.

This manual has been prepared with the following objects in mind:

1. To assemble material primarily designed for collegiate use, but in a form which the authors hope will be useful in vocational schools and in a limited way to those engaged in practical and commercial phases of the horticultural industry.
2. To present the subject in simple form, so that, if the reader's knowledge of Chemistry, for example, is limited he will not be embarrassed by technical terms in his search for information to apply to his own problems. The Chemistry of this subject is so important that it should be treated in a separate manual and in the manner best suited to the needs of those who can use it most effectively.
3. To show the relation and value of spraying as compared with other control measures. Many of the effective methods of

insect and disease control for horticultural plants are briefly reviewed and classified in Chapters I and II.

4. To acquaint the reader, not only with a few standard control measures, but with special ingredients, methods and equipment and the reasons for a rise or decline in their usefulness. It may be sufficient for some to know merely half a dozen good control measures, but such a viewpoint is too limited for the college man.

5. To provide a series of exercises for the student, which will require him to work with his hands as well as with his head. By this means he is likely to secure information which he knows how to use and can remember.

The Field of Study in Plant Disease and Insect Control.

As considered here, the subject necessarily includes a wide range of treatment. To get the most out of a course of this kind, a desirable arrangement of allied courses would provide for previous study of fundamental courses in Entomology and Botany, while the study of insects and diseases of horticultural plants should be correlated with the spraying course. The curriculum which does not allow for this arrangement should not be utterly condemned, but this timely correlation of subjects enables the student to apply what he learns in Entomology and Pathology, while he still remembers it, to his course in spraying. Such a situation is bound to have a favorable reaction on the student, and prominent educators are urging this plan of study in various major courses.

It is assumed that the student is acquiring knowledge of the fundamental principles underlying the production of horticultural plants, for the management the plants receive affects their vigor and resistance to enemies. Knowledge of the known varieties of plants is also important, not only because of their comparative merits, as reflected in the price they bring, but also because of varietal differences in resistance to disease and insects.

One can easily appreciate the value of courses in Farm Mechanics or Engineering when they are applied to the operation of spray pumps, gas engines, and dusting outfits. Machinery of this sort may lend itself beautifully to demonstration in a steam-heated, level-floored laboratory, but may not do so well

in the field. Under these latter conditions the student may more fully appreciate the details of classroom instruction.

A knowledge of Chemistry enables the student to understand the action of spray and dust materials, their compatibility in combination, their effect on insects and diseases, on the host plants and on spraying equipment.

It is evident that these allied subjects have such an important bearing on the work presented in this book that an instructor may profitably spend a portion of the time allotted to his course in fitting it properly with the related subjects, so as to make them all most useful. Undesirable duplication of effort, equipment and preparation of subject matter may also be eliminated by this plan.

The Occupations in Which this Course Should Prove Useful.

First of all, this book considers the producer and the man preparing to grow horticultural crops. Upon the activities of these men depend the occupation of most of those who deal with them.

College men who enter the employ of firms manufacturing spray and dust materials and equipment will need a sympathetic understanding of the growers' problems in pest control. Some concerns expect their field men to spend a part or all of their time in rendering service along these lines.

County agents, vocational teachers of Horticulture in the high schools, and men employed for instructional and extension work in state institutions will need to draw upon their knowledge of this subject to meet everyday problems. The type of men who are preparing for investigational work may find in this manual an elementary survey of the subject, which will serve as a guide for advanced work in a specialized field.

Administration of the Course.

It is not intended that all the exercises contained in this manual will be covered in any one course. It is hoped that the problems are sufficient in number and broad enough in range to permit the instructor to choose those best suited to his local conditions. The choice of exercises will also depend on the department in which they are administered; it will be found that

this subject is taught in some instances in the Department of Horticulture, in others in that of Entomology, while in still others the Department of Pathology will offer the work. This subject may be very effectively taught in any one of these departments, provided fundamental work in the other two is built around the course in the curriculum. A review of the work in other departments, such as has been brought together in Chapter I, entitled "The Control of Insects" and in Chapter II, "The Control of Plant Diseases," should help the student to orient himself before he has made much progress with the exercises in this manual. Laboratory periods are offered each week in the more comprehensive college or school courses; yet if sufficient equipment and field work are available there are problems enough in this manual to provide 120 to 130 hours of work. Laboratory assignments relating to spray application can never be taught in a single period and, while listed but twice in the manual—once for dormant season, and once for summer application, it is intended that such work should be continued as long as the conditions warrant, and a need exists.

The enterprising instructor will also wish to add exercises which he has prepared himself. In order to keep pace with progress in the development of control measures involving material and equipment, it may be necessary to change the present form of certain exercises from time to time or to prepare new ones.

A subject which is so vital to the horticulturist as pest control is bound to receive more and more attention within a period of six to ten years. Collegiate courses have doubled the hours and credits devoted to this subject, and the expansion is likely to continue. This increase in time will allow more thorough treatment of the subject, and will enable the instructor to increase the number of field problems undertaken.

Practical Experience.

The value of practical experience to the student, whether he is specializing in Agronomy, Dairying or Horticulture cannot be overestimated. Failure to associate the courses closely and accurately with field work is often a weakness in agricultural college administration. Out of forty-eight institutions, twenty-three do not

require any farm practice, only three require a year of it, and two require as little as six weeks. In too many instances students are allowed until graduation to fulfil this requirement, when for best results such work should precede or accompany the classroom problems. Many of our students are city bred, and the experience of the rest is usually limited, so that the leniency shown by most institutions in their requirements for practical experience are bound to handicap the student after graduation.

Field work in problems of pest control is of great importance and cannot be left entirely to the few growers who are willing to offer apprenticeships to students; nor is it possible to interest all students in this method of acquiring experience. Such training is excellent and should be acquired, but too much is usually expected of both student and grower in this respect, and such an arrangement ought not to release the institution from its responsibility for providing equipment and practical problems planned on a broad and comprehensive scale.

The following list of articles will serve as a guide in equipping a laboratory for the performance of the exercises given above:

LABORATORY EQUIPMENT

Glassware

Glass cylinders $1\frac{1}{2}$ in. by 12 in.

Graduated cylinders 250 cc.

Glass pint graduates, marked in ounces, pints and cc.'s

Glass stirring rods

Glass funnels, 6 in. and 3 in.

Hydrometers

Test tubes

Thermometers, 400° F.

Enamelware

$2\frac{1}{2}$ -gal. pails

1-gal. kettles

3-qt. kettles

10-in. pans

1-gal. measures

$\frac{1}{2}$ -gal. measures

Large spoons

Miscellaneous

Cylinder brushes
Sponges
Spring scales
Fletcher burners
Asbestos pads
Knives
Rulers

Machinery

Atomizers
Compressed air sprayers
Bucket pumps
Knapsack sprayers
Barrel pumps
Tank pumps
Traction sprayers
Power pumps
Hand dusters
Traction dusters
Power dusters
Power sprayers

Accessories

Nozzles
Guns
Rods
Y's (nozzle)
Shut-offs
Hose
Couplings
Clamps
Discharge Y's
Strainers
Assortment of tools

PART I

INSECTICIDES AND FUNGICIDES—SPRAY- ING AND DUSTING EQUIPMENT

CLASSIFICATION OF INSECTICIDES AND FUNGICIDES

Spray mixtures may be classified according to the season of application and to the purpose of application.

I. According to season

1. *Dormant*—Those that are applied during the winter and early spring while the plants are dormant.
2. *Summer*—Those applied when the plants are in leaf.

II. According to Purpose

1. *Insecticides*

- (a) Stomach or internal poisons—for controlling chewing insects.
- (b) Contact or external poisons—for controlling sucking insects.
- (c) Repellants—For protecting plants against insects of both types.
- (d) Fumigants—for controlling all types of insects.

2. *Fungicides*—Materials used for protection against fungous diseases.

3. *Combined Insecticides and Fungicides*—Combined preparations for controlling fungi and chewing or sucking insects.

STOMACH POISONS

EXERCISE NO. 1

HELLEBORE

Field Formula:

White hellebore.	10 oz.
Water.....	30 gals.

Directions:

Determine the amount of hellebore necessary to make $\frac{1}{2}$ gallon of spray. Mix this amount into the form of a paste with a little water and then dilute to $\frac{1}{2}$ gallon. Pour some of the spray mixture in a cylinder and set aside for observation.



FIG. 2.—Laboratory Equipped for the Mixing of Spray Materials.

Hellebore consists of the powdered roots of the plants *Veratrum album* and *Veratrum viridis*. It contains alkaloids which are poisonous to insects but do not affect human beings when used in the proper dilution for insecticides. It loses its strength readily

when exposed to the air but is a very effective remedy for destroying chewing insects on plants or fruits nearly ready to harvest.

Hellebore may also be applied in the dry form, either pure or diluted with flour or slaked lime at the rate of 1 oz. to from 5 to 10 oz. of the flour or lime.

Notes:

Give the color, odor, condition, etc., of materials before and after mixing. Also give the solubility of the material, rate of settling of the spray in 5, 10 and 15 minutes and any other information of importance regarding the preparation of the spray.

1. Why should hellebore be stored in an airtight container?
2. Why is hellebore usually used only on berry bushes and truck crops nearing maturity?
3. What is the cost of the hellebore for making 50 gallons of spray?

References:

- Michigan Special Bul. 73, p. 21, 1915.
U. S. Farmers' Bul. 908, p. 16, 1918.

EXERCISE NO. 2

PARIS GREEN

Field Formula:

Paris green.....	$\frac{1}{2}$ lb.
Stone lime.....	1 lb.
Water.....	50 gal.

Directions:

Determine the amounts necessary to make 1 gallon of spray. Slake the lime with hot water and dilute to full amount. Place the Paris green in a dish and add enough of the lime water to make a thin paste. Then add the paste to the 1 gallon of lime water. Set a sample of the spray mixture aside for observation.

The chemical name for Paris green is aceto-arsenite of copper and it is made by pouring boiling solutions of white arsenic and acetate of copper together. It is soluble in ammonia (NH_4OH). Commercial Paris green should contain not less than 50 per cent arsenious acid and not more than 3.1 per cent water-soluble arsenic. It should not be mixed with lime-sulphur solutions or with fungicides containing ammonia.

Paris green is used more on truck crops than elsewhere. It is a very active poison due to its high arsenic content. For dusting thoroughly mix 1 part of Paris green with 10 to 20 parts of land plaster or lime.

Purity Tests:

Test various brands of Paris green in the laboratory by taking a small quantity in a test-tube and pouring over it some NH_4OH . Any adulterations as sand or gypsum will remain undissolved in the bottom. Record results in your notes.

To test for soluble arsenic place a little of the sample in a test-tube and add about 15 c.c. of distilled water. Shake thoroughly and filter into another test-tube. Add a few drops of dilute hydrochloric acid to the filtrate so the reaction is acid, warm slightly, and allow hydrogen sulphide gas to pass through it. A yellow pre-

precipitate indicates the presence of arsenic. Place a small amount of Paris green in another test-tube and add a little hydrated lime. Follow the same procedure as for the first sample and test for soluble arsenic. Also test these brands for relative amounts of soluble arsenic, using equal quantities of each brand and record in your notes.

London Purple, a by-product in the manufacture of aniline dyes, was used formerly to a considerable extent for the same purposes as Paris green. It has always been more variable in composition than Paris green, often containing one-half of the arsenic in soluble form and therefore unsafe to use on many plants.

Formula:

London purple.....	$\frac{1}{2}$ lb.
Stone lime.....	1 lb.
Water.....	50 gals.

It is now difficult to obtain it on the market.

Notes:

Describe the physical properties of the Paris green before and after mixing. Also note the solubility and rate of settling of the materials.

1. Why should Paris green never be used on the stone fruits?
2. Why is lime added when Paris green is used alone on other plants? Mass. Bul. 201.
3. Why could Paris green not be substituted for lead arsenate in a summer spray containing lime sulphur?
4. Why is it not desirable to substitute Paris green for arsenate of lead in summer sprays containing Bordeaux mixture? Farm. Bul. 908.
5. Can soap be used with Paris green to increase its spreading and sticking qualities?

References:

- Herrick, Insects of Economic Importance, p. 17.
 U. S. Farmers' Bul. 908, p. 15, 1918.
 Fernald, Insects in Their Relation to Man, p. 45.

EXERCISE NO. 3

ARSENITE OF LIME OR CALCIUM ARSENITE

Field Formula:

STOCK SOLUTION

White arsenic	1 lb.
Sal soda	4 lbs.
Water	1 gal.

PART 2

Stock solution	1 qt.
Hydrated lime	2 lbs.
Water	50 gals.

Directions:

Boil the white arsenic and sal soda together in 1 gallon of water for 15 or 20 minutes or until all the arsenic is dissolved. Add just enough water to make up for that lost while boiling. This solution is arsenite of soda and should be stored in jugs or bottles until needed.

When ready to use, stir well, add the hydrated lime and dilute to proper strength. The addition of the lime changes the sodium arsenite to calcium arsenite which is less soluble and the active agent in the mixture. In laboratory make up $\frac{1}{4}$ pint of stock solution. Then make up 1 gallon of the complete spray and set a sample aside for observation.

White arsenic (As_2O_3) is the cheapest form of poison insecticide. It is soluble in water. It is used in the manufacture of arsenical poisons and as a poison in insect baits. Arsenite of lime can only be applied on plants resistant to arsenical injury and may be used as a substitute for Paris green.

Notes:

Describe the physical properties of the white arsenic and also of the arsenite of lime. Include observations during the process of making.

1. Why would it not be satisfactory to dilute the arsenite of soda solution and use it as a spray?
2. Why is white arsenic not used as a spray?
3. How do the arsenites compare with the arsenates in effectiveness? Mass. Bul. 201.
4. Why have the arsenates largely taken the place of the arsenites? Mass. Bul. 201.
5. What is the cost of making 50 gallons of spray?
6. How does it compare with Paris green in cost?

References:

U. S. Farmers' Bul. 908, p. 14, 1918.

EXERCISE NO. 4

ARSENATE OF LIME OR CALCIUM ARSENATE

Field Formula:

Calcium arsenate (powder)	1 lb.
Hydrated lime	3-4 lbs.
Water	50 gals.

(When calcium arsenate is combined with Bordeaux mixture, the lime is omitted.)

Directions:

Calcium arsenate and hydrated lime, when both are in powdered form, can be mixed dry and then enough water is added to make a thin paste before diluting to 50 gallons. Make $\frac{1}{2}$ gallon of spray in laboratory.

Calcium arsenate is similar to lead arsenate, the difference being that lime is substituted for the lead. This makes it cheaper than lead arsenate.

Calcium arsenate should not be used on plants with tender foliage, and when not combined with other spray materials, it is safer to use lime with it. It contains a higher percentage of arsenic oxide and therefore has a higher killing efficiency than lead arsenate, pound for pound. It is not to be recommended for spraying fruit trees except in special cases because its manufacture is not standardized and its composition is variable.

Notes:

Describe the physical properties both before and after mixing. Note the rate of settling at the end of 5, 10 and 15 minutes.

1. On what class of fruits should calcium arsenate never be used? Farm. Bull. 908.

2. What is the analysis of the particular brand which you used?

3. Why is the lime added to the spray when the calcium arsenate is used alone? Mass. Bull. 201.

4. Would you add soap to this spray to increase its sticking and adhesive properties?
5. What is the cost of making 50 gallons?

References:

Farmers' Bul. 908, p. 10.

U. S. D. A. Bul. 278, p. 12.

EXERCISE NO. 5

ARSENATE OF LEAD OR LEAD ARSENATE (Home Made)

Field Formula:

Lead acetate.....	22 oz.
Sodium arsenate.....	8 oz.
Water.....	50 gals.

Directions:

Dissolve the lead acetate in 1 gallon of water and the arsenate of soda, in $\frac{1}{2}$ gallon of water. Hot water will hasten the dissolving. When both are dissolved, mix with the rest of the water. Make 1 gallon of this spray. The above formula makes approximately the equivalent of 1 pound dry lead arsenate. Also make $\frac{1}{2}$ gallon of spray using a commercial brand of lead arsenate at the rate of 1 pound of the dry form to 50 gallons of water.

Lead arsenate is the most widely used of all poison insecticides and has a great range of usefulness. It does not injure the foliage of most plants, has good sticking qualities and remains in suspension well. It can be combined safely with most sprays. *Lead arsenate is rarely made on the farm* as the commercial brands of lead arsenate are better and cheaper.

There are three different forms of lead arsenate, the basic, neutral and acid. The acid is the most concentrated form, and the one usually sold to growers.

When commercial brands of lead arsenate are applied as a dust with a dusting outfit, a grade is used which is so fine that it will pass through a sieve having 300 mesh to the inch. Land plaster or lime is used as a carrier in dusting, at the rate of ten parts to one part of lead arsenate.

Notes:

Describe the physical properties of the ingredients and of the lead arsenate before and after mixing. Compare the rate of settling at the end of 5, 10 and 15 minutes for both spray mixtures.

1. How does lead arsenate (commercial) compare with Paris green as to cost and as to general efficiency? Farm. Bul. 856, p. 9.
2. What is the analysis of the commercial lead arsenate which you used?
3. Name two spray materials with which arsenate of lead should not be combined.
4. What are the advantages of dry lead arsenate over the paste? Mass. Bul. 201, p. 5.
5. Why is it not generally advisable to use soap with lead arsenate spray? Mass. Bul. 201, p. 12.
6. Compare the cost of making 50 gallons of both mixtures.

References:

- U. S. Farmers' Bul. 856, p. 9, 1917.
- U. S. Farmers' Bul. 908, p. 8, 1918.
- U. S. Farmers' Bul. 1038, p. 13, 1919.
- Massachusetts Bul. 201, p. 4, 1921.

EXERCISE NO. 6

COMMERCIAL BRANDS OF LEAD ARSENATE

Prepare $\frac{1}{2}$ gallon of lead arsenate spray from each of the various commercial brands furnished in the laboratory. Use at the rate of 1 pound dry lead arsenate to 50 gallons of water. Make the following observations and tabulate in your notes. Also include any observations made regarding comparisons of the various brands.

Brand	Form	Analysis	Rate of Settling in			Acidity
			5 min.	10 min.	15 min.	

References:

- Tartar and Robinson, Amer. Chem. Soc. Journal, p. 36, 1843, 1914.
- Oregon Bull. 128, 1915.
- U. S. D. A. Bull. 278, p. 12, 1915.
- U. S. Farmers' Bull. 908, p. 8, 1918.
- Mass. Bull. 189, p. 62, 1919.
- U. S. Farmers' Bull. 1038, p. 13, 1919.

EXERCISE NO. 7

LEAD ARSENATE AND STICKERS OR SPREADERS

LEAD ARSENATE AND CALCIUM CASEINATE OR LIME-CASEIN

Field Formula:

Casein-lime mixture	2½ oz.
Lead arsenate spray	50 gals.

Directions:

The casein-lime mixture is prepared by mixing thoroughly 3 ounces of powdered casein and 7 ounces of hydrated lime. The mixture may be added to the spray in the dry form or first mixed into a paste with a little water and then added to the spray. When added to the spray in the dry form, it should be added slowly while the agitator is in motion. If the mixture is first made into a paste, add water slowly in small amounts and stir vigorously until the materials combine. When the chemical action is complete, dilute to a thin paste for convenience in handling. The product formed by this reaction is calcium caseinate, a colloidal substance. The proper amount of the paste is then added to the spray.

In laboratory make up a sample of calcium caseinate using ½ the amounts given in the above formula. Also prepare 1 gallon of lead arsenate spray with the calcium caseinate made in laboratory according to the formula above, and 1 gallon of spray using the commercial calcium caseinate sticker. Set a cylinder of each aside for observation.

Calcium caseinate as a sticker has some advantages over other stickers in that it is compatible with all sprays, does not cause injury, is convenient to handle and low in cost. It is a new sticker and spreader which is being used to some extent in the Northwest, and commercially prepared brands are now offered for sale in various fruit regions. Where the pressure and volume of the outfit is low, or the work of the operator lacks thoroughness,

or the application is not timely, caseinate spreaders will add to the efficiency of the spray. Usually they are of least value to the man who sprays most thoroughly, but even here spreaders effect a more even, less disfiguring coat of poison.

LEAD ARSENATE WITH RESIN FISH-OIL SOAP

Field Formula:

Resin fish-oil soap	2 or 3 lbs.
Lead arsenate spray	50 gals.

Directions:

Dissolve the required amount of the soap in water adding small amounts at a time and stirring constantly until the soap is dissolved. Then add the soap solution to the lead arsenate spray. Make up $\frac{1}{2}$ gallon of this spray in laboratory and set a cylinder sample aside for observation.

This particular spray is desirable for spraying truck crops such as cabbage and onions, having smooth, waxy foliage resistant to arsenical injury. The soap increases the spreading and sticking qualities of the spray. The spray should be applied immediately after adding the soap.

LEAD ARSENATE AND RESIN STICKER

Field Formula:

Resin sticker	1 gal.
Lead arsenate spray	50 gals.

Directions:

The resin sticker is prepared by mixing 2 pounds of pulverized resin, 1 pound of sal soda and 1 gallon of water. Then boil this mixture from 1 to $1\frac{1}{2}$ hours or until the solution is a clear brown color. These amounts are enough for 50 gallons of spray. Make up $\frac{1}{2}$ gallon of lead arsenate spray and add the resin sticker furnished in laboratory according to the above formula. Set a cylinder sample aside for observation.

This spray is used to some extent for spraying certain smooth-leaved truck crops. The resin fish-oil soaps are used more widely for this purpose.

Notes:

Describe the physical properties of the various stickers used and of the finished sprays. Compare the sprays with each other and also with lead arsenate spray without a sticker. Discuss the preparation of the calcium caseinate.

1. Would it be safe to use calcium caseinate with sprays for orchard fruits?

2. Would it be desirable to use resin fish-oil soap with sprays for orchard fruits? Why?

3. What effect does the soap have on arsenicals? Mass. Bul. 201, p. 12.

4. Why should the spray be applied immediately after the soap is added? Mass. Bul. 201, p. 12.

5. To what sprays may soap be added?

6. What is the cost of making 50 gallons of lead arsenate spray with each of the above stickers?

References:

Farmers' Bul. 856, 1917.

Farmers' Bul. 908, 1918.

Oregon Station Bul. 169, 1920.

Mass. Bul. 201, 1921.

EXERCISE NO. 8

POISONED BRAN MASH

Field Formula:

Paris green.....	1 lb.
Bran.....	25 lbs.
Molasses (heavy grade).....	2 qts.
Water.....	2 gals.

Directions:

The Paris green and bran are thoroughly mixed together first. Then add the molasses which has been diluted with the water, and stir well. Finally add more water if necessary, to make a damp mash. The mash should not be soggy but moist and crumbly. Make up a sample in laboratory using one twenty-fifth of each of the above amounts.

There are various formulas for poisoned insect baits. Some formulas for grasshopper baits contain lemons, oranges, amyl acetate or banana oil to attract the insects but recent experiments indicate that they are not usually essential. In emergencies sawdust has been used as a carrier for the poison, with fairly good results. Three-fourths of a pound of white arsenic may be used in place of the Paris green in the above formula. Paris green, however, is more effective and its color gives the bait a greenish tinge and indicates whether the poison is uniformly distributed.

Apparently experiments conducted in various parts of the United States show that the various attractive ingredients such as citrus fruits, bananas, molasses, etc., differ in their power to attract, depending upon the locality from which the observations were reported. For instance, in some localities citrus fruits were apparently most attractive, while in other sections of the country opposite results were obtained. These variable results, reported from different sections may be due to differences in climatic

conditions or differences in age of insects at the time the tests were made.

Keep children, livestock and poultry away from mash.

Notes:

Record amounts of each material used in laboratory and the weight of the finished mash.

1. How is this material used for grasshoppers, including rate, method and time of application? Farm. Bul. 908.
2. How is this material used for cutworms? Farm. Bul. 856.
3. What is the cost of making the above formula?

References:

Jour. Econ. Ent., Vol. 14, No. 3, pp. 281, 285, 292.

CONTACT POISONS

EXERCISE NO. 9

COMMON SOAP

Field Formula:

Laundry soap	1 lb.
Water	6 gals.

Directions:

Slice the soap thinly and dissolve in a gallon of hot water and dilute to 6 gallons. Make up $\frac{1}{2}$ gallon of this soap spray and set cylinder aside for observation.

The ordinary laundry soap sprays are very useful and convenient as a contact insecticide against plant lice where only a few plants in the garden or in the house are to be treated. Laundry soap is always on hand and can be conveniently made up in the form of a spray in a short time. However, whale-oil or fish-oil soaps are better.

The soap solutions kill the insect by dissolving the tissues, usually entering through the tracheae or air tubes. The addition of 1 fluid ounce of nicotine sulphate of 40 per cent strength to 6 gallons of the soap spray will greatly increase its effectiveness.

Notes:

Describe the physical properties of the spray.

1. With what sprays should soap not be combined? Farm. Bul. 908.
2. What is the result when soap is combined with Bordeaux mixture or lime sulphur sprays? Mass. Bul. 201.
3. Name four different types of soap sprays. Mass. Bul. 201.
4. What type of insects are controlled by soap sprays? Farm. Bul. No. 856.
5. What is the cost of making 50 gallons of spray?

EXERCISE NO. 10

FISH-OIL OR WHALE-OIL SOAP

Field Formula:

Fish-oil or whale-oil soap.....	1 lb.
Water.....	6 gals.

Directions:

Slice the soap thinly, dissolve in hot water and dilute to 6 gallons of spray. Make up $\frac{1}{2}$ gallon of this soap spray and set cylinder aside for observation.

The names fish-oil soap and whale-oil soap are used interchangeably because of their similarity although few are made from whale-oil.

The fish-oil soaps are made from fish oils combined with either caustic soda or potash. Caustic soda soaps will not usually contain more than 30 per cent water but the potash soaps frequently contain 70 per cent water, and for these brands a larger amount of soap is necessary than indicated in this formula. The soda fish-oil soaps are of harder consistency than those made with caustic potash.

When used as a foliage spray for soft-bodied insects, like aphids, its effectiveness will be increased by the addition of 40 per cent nicotine sulphate at the rate of 1 fluid ounce to 6 gallons of spray. When nicotine sulphate is used the amount of soap may be reduced to 6 ounces to 6 gallons of water.

Fish-oil soap has been used in the past but is not now recommended as a dormant spray for the control of scale insects. When used the rate is 2 pounds soap to 1 gallon of hot water applied while hot.

Several commercial firms are manufacturing fish-oil soaps which are proving satisfactory in field use. One firm offers four kinds for sale. One kind is a soda soap semi-hard in character. Another is a flowing syrup potash fish-oil soap. A third is a

flowing syrup potash fish-oil soap with nicotine added. The fourth is a rosin fish-oil soap. From the standpoint of ease of handling, the second and fourth kinds of soap are the easiest forms to use in the field.

Notes:

Describe the physical properties of the fish-oil soap and also of the finished spray. Compare with common soap spray in regard to ease of going into solution, and also compare cost.

1. In what other way may fish-oil soaps be used besides as a control for soft-bodied sucking insects? Farm. Bul. No. 908.

2. What is the cost of making 50 gallons of spray for control of plant lice?

3. What is the cost of making 50 gallons of spray for control of scale insects?

EXERCISE NO. 11

FISH-OIL SOAP

(Home Made)

Field Formula:

Caustic soda	6 lbs.
Water	$\frac{1}{2}$ gal.
Fish-oil	$3\frac{1}{4}$ gals.

Directions:

Completely dissolve the caustic soda in the water and then add the fish-oil slowly while stirring vigorously. Continue stirring for about 20 minutes after the last of the oil has been added and until the soap is complete. The fish-oil and caustic soda combine readily at ordinary summer temperatures without aid of external heat. Make up $\frac{1}{50}$ of the above amounts (473 c.c. = 1 pt.).

Use at the rate of 1 pound of the soap to 6 gallons of water. Make up $\frac{1}{2}$ gallon of the spray, using the home-made soap, and compare with the spray made using the commercial soap.

Notes:

Describe the physical properties of the home-made fish-oil soap and compare with the commercial soap. Weigh the finished soap and record in your notes with the weights of the ingredients used. Include observations on the mixing of the ingredients to make the soap.

1. How many pounds will the above formula make?
2. What will the cost be per pound?
3. What is the cost of preparing 50 gallons of spray?

References:

- U. S. Farmers' Bul. 856, p. 7, 1917.
- U. S. Farmers' Bul. 908, p. 36, 1918.
- U. S. D. A. Bul. 707, p. 24, 1918.

EXERCISE NO. 12

PYRETHRUM

Field Formula:

Pyrethrum.....	1 oz.
Water.....	2 gals.

Directions:

Mix the pyrethrum powder with the water and let stand for 24 hours before using. For immediate use after mixing, first make a decoction by adding the pyrethrum to 1 quart of boiling water and allowing the mixture to stand for from 5 to 10 minutes. Then add the remainder of the water and it is ready to apply. Make up $\frac{1}{2}$ gallon of this spray in laboratory.

Pyrethrum is a contact insecticide and is especially useful for controlling soft-bodied insects and larvae not protected by hairs, as young cabbage worms on cabbage and cauliflower plants which are soon to be harvested. The insecticidal value of pyrethrum is due to certain volatile oils. These oils are not detrimental to human beings. The insecticidal properties last only a short time after the application is made.

Pyrethrum may also be applied as a dry powder, either pure or diluted with flour or air-slaked lime at the rate of one to three. When diluted, it should be allowed to stand for 24 hours in a closed container after thoroughly mixing with the diluent.

Notes:

Describe the dry powder as to appearance, odor, etc. Also describe the properties of the finished spray.

1. Why should pyrethrum be stored in air-tight receptacles? Mass. Bul. 201.

2. Why is it necessary that this material come in contact with the insect in order to get results? Mass. Bul. 201.

3. What benefit is to be derived by mixing the powder with

flour or air-slaked lime when applied as a dust? Mass. Bul. 201.

4. What is the cost of making 50 gallons of spray?

References:

Herrick, Insects of Economic importance.

U. S. Dept. of Agric. Bul. 707, p. 4, 1918.

U. S. Dept. of Agric. Bul. 771, 1919.

Mich. Ext. Bul. 4 rev. p. 11, 1919.

EXERCISE NO. 13

HOMEMADE TOBACCO SPRAY

Field Formula:

Tobacco stems.....	25 lbs.
Water.....	50 gals.

Directions:

There are two methods by which the nicotine may be extracted. One method which is very simple and convenient, is to soak the stems in the full amount of water for 24 hours with occasional stirring. After straining the solution, it is ready for use.

The other method is to place the stems in the water, heat to the boiling point and allow to cool. Strain the solution and it is ready for use.

In either case about 70 to 80 per cent of the nicotine in the stems will be extracted. After extracting the nicotine, the stems are still of some value as a fertilizer. Make up $\frac{1}{2}$ gallon of spray by the second method and fill a glass cylinder for observation.

The nicotine content varies greatly with different portions of the plant. There are also varietal and regional differences. Hence it is impossible to recommend a formula which will contain a uniform nicotine content, as is possible with commercial nicotine extracts. Analyses of various kinds of tobacco may be found in Table II, Farmers' Bulletin 908, p. 41, and in Table V, Virginia Bulletin 208, p. 15.

TOBACCO DUST

Tobacco dust has long been used to control insects infesting the roots of plants, as for example, the woolly apple aphid. Sometimes it is also used for dusting low growing plants for aphid control, and among these plants are currants and gooseberries. It is also a standard control for cucumber beetles on young plants.

The effectiveness of the dust depends upon its fineness, the

amount of nicotine it contains, and upon the weather. With plenty of moisture in the soil the nicotine leaches out, destroying the insects to a greater or less extent.

Tobacco dust may be used to advantage for control of woolly aphis, provided it is obtained cheaply enough. However, the grower should make sure that the dust he is buying is not the kind sold for fertilizer. Virginia Bulletin 208 states that tobacco stems have a fertilizing value of \$10 per ton after their nicotine is extracted.

As explained in methods of preparing home-made tobacco sprays, tobacco stems do not contain a uniform nicotine content. The same holds true for tobacco dust and definite recommendations for amounts to be used cannot be made.

Notes:

Describe the physical properties of the finished spray.

1. Why should the tobacco solution never be boiled? Farm. Bul. 908.

2. Why should tobacco sprays always be made up fresh? Farm. Bul. 908.

3. What is the cost of making 50 gallons of spray?

References:

Farmers' Bul. 908, p. 41, 1918.

Virginia Bul. 208, 1914.

Herrick, Insects of Economic Importance, 1915.

EXERCISE NO. 14

NICOTINE SULPHATE

Field Formula:

Nicotine Sulphate (40% Nicotine).....	$\frac{1}{2}$ pt.
Water.....	50 gals.

Directions:

To prepare the spray, add the nicotine sulphate to the water and stir to get the materials well mixed. This formula is equivalent to a 1 to 800 dilution. Make up a sample of spray in laboratory using $\frac{1}{2}$ gallon of water. Fill a glass cylinder and set aside for observation.

When the nicotine sulphate is used alone for spraying, add 3 pounds of soap to every 50 gallons of spray or enough to soften water. However, the soap must not be used when combined with other sprays as Bordeaux or lime sulphur, where dangerous combinations will result. Either the laundry soap or fish-oil soap may be used. Dissolve the soap in a portion of the water by boiling and add to the balance of water and nicotine sulphate. Make up $\frac{1}{2}$ gallon of spray, using the soap, and set aside a cylinder full for observation. (473 c.c. = 1 pt.)

The commercial nicotine sulphate comes in highly concentrated form (40 per cent nicotine) and is easy to dilute. The diluted spray should contain not less than .05 to .06 per cent of nicotine.

Notes:

Describe the physical properties of the nicotine sulphate and of the completed spray. Compare with the homemade decoction made in the previous exercise and also with the spray containing soap.

1. What type of insect is controlled by the nicotine sprays? Farm. Bul. 908, p. 40.

2. What are the advantages of nicotine sulphate over other contact insecticides used during the growing season? Farm. Bul. 908, p. 40.

3. Give two reasons why it is best to add soap when nicotine sulphate is used alone. Mass. Bul. 201, p. 20.

4. Why should soap not be used when nicotine sulphate is combined with certain other sprays. Mass. Bul. 201, p. 20.

5. How does nicotine sulphate kill the insect? Mass. Bul. 201, p. 20.

6. How does the addition of soap increase the effectiveness of nicotine sulphate? Mass. Bul. 201, p. 20.

7. What is the cost of making 50 gallons of spray without the soap? With soap?

References:

Jour. Econ. Ent. Vol. 8, p. 199, 1915.

U. S. Dept. of Agric. Bul. 416, p. 63, 1917.

U. S. Farmers' Bul. 1007, p. 10, 1919.

EXERCISE NO. 15

NICOTINE OLEATE

Field Formula:

Free nicotine solution (40%).	10 parts
Com. oleic acid (red oil)	7 parts

Directions:

Any 40 per cent free nicotine solution such as "Nicofume" or "Nikoteen" liquid may be used. Combine the free nicotine solution with the commercial oleic acid by pouring one into the other and stirring constantly until a thorough mixture is obtained. The resulting mixture which will resemble vaseline in appearance is nicotine oleate and this will mix with water producing an emulsion. For use, the nicotine oleate is mixed with water, preferably soft water, at the rate of 1 pint to 25 gallons of water. For most insects found in the greenhouse such as aphids, white fly and red spider, this dilution (1 to 200) will be efficient.

In laboratory make up $\frac{1}{4}$ pint of nicotine oleate and 1 gallon of the spray.

Nicotine oleate is a new contact insecticide for the control of insects such as white flies, plant lice, thrips, soft scales and mealy bugs, particularly in greenhouses. It was introduced by William Moore in 1918, and gives promise of limited use in greenhouses. It is especially efficient because of its spreading properties and its dissolving effect on the waxy secretions of such insects as white fly. It is non-volatile like nicotine sulfate and should not be applied to such edible crops as lettuce and spinach within 3 or 4 weeks prior to cutting. Nicotine oleate is not injurious even to the most delicate plants when used at a concentration somewhat greater than the above formula.

Such experimental work with nicotine oleate as has been reported has been done under indoor greenhouse conditions. It is possible that under field conditions a different dilution may be found necessary.

Notes:

Describe the physical properties of the materials used. Discuss the mixing of the materials and the changes taking place. Describe the properties of the products formed and of the finished spray.

1. What is the cost of making 50 gallons of spray?

References:

William Moore, A Promising New Contact Insecticide.
Jour. Econ. Ent., Vol. 11 No. 3, June, 1918, pp. 341-342.

EXERCISE NO. 16

KEROSENE EMULSION

Field Formula:

Laundry or fish-oil soap	$\frac{1}{2}$ lb.
Water	1 gal.
Kerosene	2 gals.

Directions:

Shave the soap finely and dissolve in the water by boiling. Hard water should first be softened by adding a little sal soda. Remove from the fire and add the kerosene while still hot. Agitate vigorously, using a spray pump and pumping the mixture back into itself through a fine nozzle for 5 or 10 minutes. Small amounts may be stirred vigorously by using a rotary egg beater. The stock solution will last for some time if well made but it is better to make up as needed. Do not dilute until ready to use.

For soft-bodied insects, dilute 1 part of the stock emulsion with 15 parts of water. For scale insects a former recommendation was to dilute 1 part of the stock emulsion with 5 parts of water. Only the former dilution can be used on foliage and should be applied only on bright sunshiny days to prevent injury to the foliage. Agitate well after adding the water. Generally speaking, kerosene emulsion is less effective and useful and more likely to injure foliage than nicotine sulphate.

Make up $\frac{1}{16}$ of the above field formula and mix up a half-gallon of each of the dormant and summer sprays. Set a cylinder of each spray and one of the stock emulsion aside for observation.

Kerosene emulsion may be used for the control of white grubs in the soil. For this purpose, dilute 1 part of the stock solution with 8 gallons of water and apply to the surface of the soil at the rate of 1 gallon to 6 or 8 square feet. It may be applied directly to lawns or other vegetation. Immediately after the application, sprinkle copiously with water to wash the kerosene emulsion in the soil. The application is made as soon as grubs become con-

spicuous, which is usually about the middle of August. Kerosene when applied as a film on ponds and pools is efficient for the control of mosquitoes.

Experiments have shown that fusel oil (amylic alcohol) when added to the kerosene emulsion formula helps to produce a better emulsion. Its practical value has not been fully demonstrated.

The formula is as follows:

Whale-oil soap.....	4½ lbs.
Fusel oil.....	2½ pts.
Kerosene.....	17 pts.

Notes:

Describe the physical properties of the stock emulsion and note the changes that take place while agitating the mixture. Note any changes that take place in the appearance of the stock emulsion after standing 15 minutes. Also describe the properties of the finished spray.

1. What sprays should not be combined with kerosene emulsion? Why? Mass. Bul. 201.

2. Compare kerosene emulsion with nicotine sulphate as to desirability for spraying. Mass. Bul. 201.

3. How do oil sprays kill the insect? Mass. Bul. 201.

4. What is the cost of making 50 gallons of spray, summer strength?

5. What is the cost of making 50 gallons of spray, dormant strength?

References:

Mich. Special Bul. 73, p. 21, 1915.

Mass. Bul. 177, p. 142, 1918.

U. S. Farmers' Bul. 194, p. 13, 1918.

No. Carol. Bul. 242, p. 22, 1921.

EXERCISE NO. 17

COLD STIRRED PARAFFIN OIL EMULSION

Field Formula:

Laundry or fish-oil soap	8 lbs.
Paraffin oil	2 gals.
Water	1 gal.

Directions:

Dissolve the soap in hot water. The soap solution should not be too hot or cold when added to the oil. If a soft soap or thick solution of soap is used the oil may be mixed with it without the aid of heat. Add the oil slowly while the mixture is being stirred. After each addition of oil, stir thoroughly before adding more. This stock emulsion is diluted at the rate of 1 part of the emulsion to 50 parts of water.

Make up a stock emulsion in the laboratory using $\frac{1}{32}$ of the above amounts. Also make up $\frac{1}{2}$ gallon of spray from the stock emulsion. Set a sample of each aside for observation.

This emulsion is used for the control of white flies and scale insects in the citrus groves of Florida. This emulsion has the distinct advantage of cold stirring and it can also be applied to trees in foliage.

Notes:

Describe the physical properties of the stock solution, and also of the completed spray. Describe the changes taking place during mixing.

1. What is the cost of making 50 gallons of spray?

EXERCISE NO. 18

BOILED PARAFFIN OIL EMULSION

Field Formula:

Laundry or fish-oil soap.....	2 lbs.
Paraffin oil.....	2 gals.
Water.....	1 gal.

Directions:

Shave the soap and dissolve in hot water. Add the oil and heat to boiling point. Remove from the fire and emulsify the mixture by forcing through a small hand pump. This stock emulsion is diluted for spraying at the rate of 1 part stock emulsion to 50 parts of water. Make up a stock emulsion using $\frac{1}{3\frac{1}{2}}$ of the field formula. Also make up $\frac{1}{2}$ gallon of spray, using the stock emulsion. Set a sample of each aside for observation.

The boiled emulsion is an improvement over the cold stirred emulsion in that it requires much less soap and is therefore much cheaper. Where large quantities of this spray are used, the soap is quite an item. This spray is used for the same pests as the cold stirred emulsion.

Notes:

Describe the physical properties of the stock solution and also of the completed spray. Compare with the cold stirred emulsion in regard to appearance and ease of mixing.

1. What is the cost of making 50 gallons of spray?

References:

- Farmers' Bul. 933.
Florida Bul. 148, p. 176, 1918.

EXERCISE NO. 19

CRUDE OIL EMULSION

Field Formula:

Laundry or fish-oil soap	5 lbs.
Lye (caustic soda)	1 lb.
Crude Oil	6 gals.
Water	44 gals.

Directions:

Dissolve the soap in 3 to 4 gallons of boiling water and pour into spray tank. Add the lye and water to make up to the 44-gallon mark. Start the agitator and slowly pour in the crude oil, continually agitating for a few minutes after the oil has been added, and then the emulsion is ready to spray on the trees. For laboratory purposes make up $\frac{1}{2}$ gallon of the above spray mixture and set a sample aside in glass cylinder for observation.

This emulsion is used as a dormant spray for the control of European fruit lecanium and European pear scale, cherry scale, and for the destruction of lichens infesting deciduous fruit trees on the Pacific coast.

While applying the spray this emulsion should be thoroughly agitated. It is essential to wet the entire tree area and from 8 to 10 gallons of material should be used to the tree.

TREE INJURY FROM CRUDE OIL

Crude petroleum should not be used on deciduous trees as a spray material except when buds are entirely dormant. Under California conditions fruit buds where the oil has penetrated may sometimes be injured or killed, but these buds are only a small percentage of the total number. The remainder seem to be stimulated to a more vigorous growth, and the foliage produced is apparently resistant to disease. In dry seasons the application of crude oil emulsion may be delayed to advantage until the swelling of the buds.

A natural crude petroleum testing about 23° Baumé is the best form to use, but heavier oils testing as low as 18° have given satisfaction. The oils which are used in California differ from those used in the east in that they have an asphaltum base, while those used in the east usually have a paraffin base.

Notes:

Describe the physical properties of the completed spray. Note any changes which take place after standing 10 minutes, and discuss ease of mixing the materials.

1. What is the cost of making 50 gallons of spray?

References:

Farmers' Bul. 908, 1918.

California Cir. 227, p. 58, 1921.

EXERCISE NO. 20

MISCIBLE OILS

Field Formula:

Miscible oil.	1 gal.
Water	15 gals.

Directions:

Make up a half-gallon sample of each of the brands of miscible oils in laboratory. Pour the oil into the water. Do not use ice cold water. Warm water makes the mixing easier. Set a cylinder of each aside for observation.

Commercial brands of oil should be thoroughly stirred before mixing with water.

If they will not emulsify properly send them back to the manufacturer in exchange for fresh material. This uncertainty surrounding the emulsifying properties of commercial oils makes it imperative that the grower test his materials sufficiently in advance of the dormant spray to arrange an exchange, if necessary.

Miscible oils are mineral oils which are finely subdivided into minute globules usually mixed with a soap made from a vegetable oil and an alkali. When such an oil is mixed with water the globules are evenly distributed throughout the water. The miscible oil sprays kill the insect by giving off volatile substances which enter the tracheae and are absorbed by the tissues, thus preventing absorption and assimilation of oxygen.

Miscible oil sprays are more agreeable to apply than lime sulphur. They do not corrode metals, injure paint or harness, nor burn the eyes and skin.

They do have a tendency to separate the rubber from the fabric of spray hose. The miscible oils are, moreover, more expensive to use than lime sulphur. Experiments indicate that their continued use results in cumulative injury to the plant. Even at weaker dilutions, these oils should never be used as a summer spray.

Notes:

Describe the physical properties of the miscible oils before and after mixing with water. Also compare the various brands in regards to ease of mixing, presence of free oil, etc.

1. When and for what pests are the miscible oils applied? Farm. Bul. 908.

2. What weather conditions are best for applying miscible oil sprays? Farm. Bul. 908.

3. What is the cost of making 50 gallons of spray?

References:

Herrick, Insects of Economic Importance, p. 22, 1915.

Felt, N. Y. R. 31, p. 71, 1916.

U. S. Farmers' Bul. 908, p. 31, 1918.

Mass. Bul. 177, p. 143, 1918.

Better Fruit, p. 9, March, 1922.

Better Fruit, p. 9, May, 1922.

Better Fruit, p. 20, June, 1922.

EXERCISE NO. 21

HOMEMADE MISCIBLE OIL

Field Formula:

Part I—Emulsifier

Menhaden Fish oil.....	5 gals.
Carbolic acid (liquid crude).....	4 gals.
Caustic soda (granulated).....	8 lbs.
Kerosene.....	7 gals.
Water.....	10 gals.

Part II—Miscible Oil

Emulsifier.....	8 parts
Paraffin oil.....	35 parts
Rosin oil.....	5 parts
Water.....	1 part

Directions:

First make the emulsifier or soap solution by placing the fish oil, carbolic acid and caustic soda in a kettle. The kettle should not be over half full as the contents will foam when heated. Start the fire and stir mixture until caustic soda is dissolved. Then place cover over kettle. Do not allow the flames to reach the top of the kettle, as the mixture is inflammable.

Insert the thermometer in the mixture from time to time to note the temperature. The material begins to foam at 260° F. At 280° F. check the fire and at 290° to 300° remove the kettle from the fire. Pour in the kerosene and stir. When the temperature has dropped to 212° F. add the water and stir thoroughly. The completed emulsifier, if well made, will keep several seasons.

The miscible oil may be made in clean barrels or other containers free from acids or alkalies. Pour in emulsifier and stir thoroughly. Add the paraffin oil, rosin oil and water in the order named. Stir briskly until a smooth creamlike mixture is obtained. This then is the complete miscible oil. To test, pour a few drops

in a glass of water. If a milklike emulsion results, the miscible oil has been properly made.

In laboratory, make up the emulsifier, using $\frac{1}{100}$ of the field formula. Set a sample aside for observation. Using $\frac{1}{4}$ pint of the emulsifier make up the miscible oil and set a sample aside for observation. Also make up $\frac{1}{2}$ gallon of spray at the rate of 1 part of miscible oil to 15 parts of water. Set a sample aside for observation.

Making miscible oil at home for commercial orchard work is not recommended. The special oils required as ingredients are difficult to obtain, and in the process of cooking, the flames as they lick the side of the kettle, may easily ignite the mixture and spoil the entire batch. Commercial miscible oils are not dangerous to handle since they may be kept away from fire.

It may not often be practicable to illustrate the difficulties of making miscible oil in the laboratory, although it has been made successfully by students.

Notes:

Describe the changes which take place during the preparation of the various mixtures. Describe the properties of each mixture. Compare the homemade miscible oil with the commercial brands and also the sprays made from them.

1. How many gallons of miscible oil will the above formula make?
2. What is the cost per gallon of the homemade miscible oil as compared with the commercial brands?
3. What is the cost of making 50 gallons of spray using the homemade miscible oil?

References:

- N. Y. Sta. Bul. 281, 1906.
- Conn. Bul. 54, 1909.
- Wash. Popular Bul. 64, 1914.
- Mass. Hort. Soc. I, p. 87, 1914.

EXERCISE NO. 22

CONCENTRATED LIME SULPHUR

Field Formula No. 1:

Stone Lime (90% calcium oxide)	40 lbs.
Sulphur	80 lbs.
Water	50 gals.

Field Formula No. 2:

Stone Lime	50 lbs.
Sulphur	100 lbs.
Water	50 gals.

Field Formula No. 3:

Stone Lime	60 lbs.
Sulphur	120 lbs.
Water	50 gals.

Directions:

The object of this exercise is to determine which formula is the most economical in labor and material costs for adoption in field cooking of lime sulphur for a commercial orchard.

The class will be divided into three groups. Each group will use the formula assigned to them and make up two samples of concentrated lime sulphur, 1 gallon of each, in one case using the stone lime as given above and in the other, using hydrated lime. When computing the amount of hydrated lime, add about 33 per cent to the weight given for stone lime.

Slake the stone lime with hot water (to hasten the process) and add the sulphur either dry or in the form of a paste, after slaking is well started. Keep well stirred while slaking. When the slaking is complete, add the remainder of the water, mark the height of the liquid on a stick and boil for from 40 to 60 minutes or until the solution becomes a very dark reddish brown. Add water from time to time to maintain at constant volume.

When using the hydrated lime, the two materials may be

mixed dry, then made into a paste and finally diluted with the required amount of water. Boil the same as above. Do not allow the solution to turn green, as this indicates that the sulphur compounds are breaking down and free sulphur is liberated. When this point is reached the density of the solution begins to decrease. When pure stone lime is used which contains more than 90 per cent calcium oxide, the solution can be boiled a long time before any breaking down occurs. The presence of magnesium in poor lime hastens the breaking down of the sulphur compounds.

Pour some of the solution in a kettle and set in a pan of cold water to cool. Stir well, fill glass jar and set aside until next period.

Notes:

One man in each group will report to the other groups on his results at a time specified by the instructor. Each student will be required to have complete results on all methods. At the end of the laboratory period arrange results neatly, preferably in tabular form and include the following: Field Formula; Form of Lime; Time of boiling; Degrees Baumé; per cent of Sludge; Cost of Materials to make 50 gallons; Cost of making on basis of 32° B. Finally write up a brief summary of results obtained and make some general comparisons.

1. What chemical substances make up the clear lime sulphur solution? Mass. Bul. 201.

2. Show by chemical equation how lime sulphur is oxidized. Mass. Bul. 201.

3. Is the hydrometer test always an accurate indication of the relative efficiency of lime sulphur solutions? Mass. Bul. 201.

4. Does the free sulphur present have any value as a fungicide? Mass. Bul. 201.

5. How does lime sulphur solution kill scale insects? See introduction.

References:

- Geneva, N. Y., Bul. 309, 1909.
- Geneva, N. Y., Bul. 329, 1910.
- Oregon Research Bul. 3, 1914.
- U. S. Dept. Agric. Bul. 416, p. 67, 1917.
- Geneva, N. Y., Bul. 415, p. 24, 1916.
- U. S. Farmers' Bul. 908, p. 18, 1918.
- Mass. Bul. 177, p. 143, 1918.

FUNGICIDES

EXERCISE NO. 23

COPPER SULPHATE

Field Formula:

Copper sulphate	2 to 3 lbs.
Water	50 gals.

Directions:

Dissolve the copper sulphate in some hot water and dilute to 50 gallons of water. When used in large amounts it is better to make up a stock solution at the rate of 1 pound to 1 gallon. The copper sulphate can be dissolved in cold water by suspending the crystals just below the surface. Make up $\frac{1}{2}$ gallon of spray and set a cylinder full aside for observation.

This spray is very efficient as a fungicide but can only be used as a dormant spray. It can be used on peach trees for the control of leaf curl when there are no scale insects to contend with. This spray is also used on dormant grape vines and the supporting trellis as an antiseptic measure.

Copper sulphate and sodium chloride dissolved in water at the rate of 1 pound of each to 5 gallons is used to control stinking smut of wheat. The seed is soaked in this solution for 10 minutes. To prevent injury to the seed by the copper sulphate the seed is soaked in lime water for 10 minutes immediately after taking it out of the copper sulphate solution. The seed should be planted the following day.

In the West a dust mixture of copper sulphate and air-slaked lime, equal parts of each, is used to a large extent. It is thoroughly mixed with the seed at the rate of 2 ounces of the dust to every bushel of seed. Copper carbonate dust alone is also used at the rate of 2 ounces to every bushel of wheat seed for the control of stinking smut.

The hot water treatment of seed wheat will control both the loose and stinking smut.

Finely ground copper sulphate mixed with hydrated lime and

applied as a dust has given satisfactory results on apples and potatoes. Up to the present time it has not been used very extensively but shows great promise.

COPPER SOAP SPRAY

A copper soap spray consisting of $\frac{1}{2}$ pound copper sulphate, 3 pounds resin fish-oil soap, 50 gallons of water applied to tomatoes for leaf spot has proved as effective as Bordeaux mixture.

All solutions containing copper sulphate should be handled only in copper, wooden or earthenware vessels.

COPPER SOAP DUST

Copper soap dust, a new fungicide prepared from copper sulphate and fish-oil soap. controlled tomato leaf spot just as effectively as 4-4-50 liquid Bordeaux mixture in 2 years of experimental work. It spreads, floats and adheres better than any of the commercial brands of Bordeaux dust according to Pritchard and Porte of the Bureau of Plant Industry, Washington, D. C. It is also cheaper than liquid Bordeaux when cost of application is considered, and it is more easily and quickly applied.

COPPER LIME DUST

Copper lime dust was first tried out in an experimental way in 1918 by Sanders and Kelsall in Nova Scotia. The formula they used was as follows:

Dehydrated copper sulphate.....	12 lbs.
Arsenate of lime.....	10 lbs.
Hydrated lime.....	78 lbs.

This mixture proved to be much finer than 90-10 sulphur-lead dust and therefore covered more tree area. On this account a 10-5-85 formula of copper lime dust will be tested to see if it will give better control of apple scab. The 8-4-88 mixture gave practically as good control of apple scab as Bordeaux mixture, and much better control than sulphur dust.

Copper lime dust and Bordeaux mixture were compared for 2 years in the control of late blight on potatoes, with one proving just about as effective as the other. In another experiment carried

on by Pritchard and Porte this dust mixture gave effective control of leaf spot on the tomato.

Notes:

Describe the physical properties of the copper sulphate and of the finished spray.

1. How does it compare in cost with 5° Baumé lime sulphur?
2. What is the cost of making 50 gallons of spray?

References:

- Hesler and Whetzel, Manual of Fruit Diseases, 1917.
New Jersey Bul. 345, p. 40, 1920.
Science, Vol. 52, p. 540, 1920.
Purdue Ext. Bul. 100, 1921.
Phytopathology, Vol. 9, p. 554, 1919.
Phytopathology, Vol. 11, p. 227-9, 1921.

EXERCISE NO. 24

AMMONIACAL COPPER CARBONATE

Field Formula:

Copper carbonate.....	6 oz.
Ammonia (26° Bé.).....	3 pts.
Water.....	50 gals.

Directions:

Dissolve the copper carbonate in the ammonia. Then add the water. The copper carbonate may be first made into a paste with a little water before adding to the ammonia. The spray mixture loses strength on standing exposed to the air and therefore should be made fresh each time it is needed.

The solution of copper carbonate and ammonia will keep indefinitely in glass-stoppered bottles. Do not use any more ammonia than is necessary to dissolve the copper carbonate. Make up a 1 gallon sample of spray and set cylinder full aside for observation.

Ammoniacal copper carbonate upon drying leaves no stain and is therefore to be preferred to Bordeaux mixture for spraying ornamental plants and fruits or vegetables nearing maturity. It is more likely to cause injury and is less effective as a fungicide than Bordeaux.

The powdered copper carbonate is used in the West to treat wheat seed for the control of stinking smut. Two ounces of the powder are mixed with every bushel of seed.

Notes:

Describe the physical properties of the finished spray, and of the materials used in making the spray.

1. Would this spray be desirable for orchard spraying? What is the reason for your answer?

2. On what particular crops can this spray be used?

References:

Farmers' Bul. 243, 1906.

Stevens and Hall, Diseases of Economic Plants, 1910.

Ohio Bul. 309, 1917.

Phytopathology, Vol. 7, p. 235, 1917.

U. S. D. A. Bul. 712, 1918.

EXERCISE NO. 25

BURGUNDY MIXTURE

Field Formula:

Copper sulphate	1 lb.
Sodium carbonate (Sal soda)	1½ lbs.
Water	50 gals.

Directions:

This spray is made up in the same way as Bordeaux mixture. Each chemical is dissolved separately in a convenient amount of water. Stock solutions at the rate of 1 pound to 1 gallon are very convenient. Dilute the copper sulphate with the remainder of the water and add the sal soda solution. Make up 1 gallon of spray in laboratory and set a cylinder full aside for observation.

This spray is used as a substitute for Bordeaux mixture to avoid staining the foliage or fruit.

Notes:

Describe the physical properties of the finished spray. Note rate of settling at the end of 5, 10 and 15 minutes.

1. What is the cost of making 50 gallons?

Reference:

Stevens and Hall, Diseases of Economic Plants, 1910.

EXERCISE NO. 26

POTASSIUM SULPHIDE

Field Formula:

Potassium sulphide.....	3 oz.
Water.....	10 gals.

Directions:

Dissolve the potassium sulphide in a convenient amount of water and add to the remainder. Make up $\frac{1}{2}$ gallon of spray in laboratory and set a cylinder full aside for observation.

This spray should be freshly prepared each time as it loses strength on standing. It is also important to keep the potassium sulphide in a well-stoppered bottle.

This spray is used as a substitute for Bordeaux mixture to avoid spotting the fruit when it nears maturity. It is very efficient against the powdery mildews but not as efficient as the copper sprays for the general control of fungous diseases. It is used largely for spraying gooseberries, and also on currants and rose bushes, whenever powdery mildew occurs.

Solutions of potassium sulphide are caustic against delicate insects and can be used against caterpillars protected by silken tissue. The sulphide softens and decomposes the tissues and penetrates the body where hydrogen sulphide is liberated, thus killing the insect. It has been found that currant worms drop from the bush when sprayed with potassium sulphide and do not return.

Notes:

Describe the physical properties of the finished spray. How does it compare with ammoniacal copper carbonate in case of mixing?

1. What insecticides should not be combined with potassium sulphide?
2. What is the cost of making 50 gallons of spray?

References:

Farmers' Bul. 243, 1906.
Ohio Bul. 309, 1917.

EXERCISE NO. 27

BORDEAUX MIXTURE

Field Formula:

(Standard)

Copper sulphate.....	4 lbs.
Stone lime.....	4 lbs.
Water.....	50 gals.

The abbreviated form of this formula is 4-4-50. (In ordering stone lime, specify that it shall contain 90 per cent calcium oxide. Unless air is excluded from the container, stone lime should be taken at once.)

Hydrated lime may be used in place of stone lime, and this form may be stored indefinitely in a dry place. The amount used in all formulas is 50 per cent greater than the amount of stone lime.

Object of Exercise:

The object of this exercise is to determine the value of the various methods of mixing outlined below, all of which have been taken from the literature on Bordeaux.

Directions:

Make up a pint of stock solution of lime and a pint of stock solution of copper sulphate at the rate of 1 pound to 1 gallon of water. Slake the lime in hot water to hasten the process, and make up to 1 pint. Dissolve the copper sulphate by boiling. Using these stock solutions prepare samples of Bordeaux mixture according to the following methods and set a cylinder of each aside for observation. Label each cylinder.

1. Take 40 c.c. of copper sulphate solution and dilute to 250 c.c. Take 40 c.c. of lime solution and dilute to 250 c.c. Pour the two solutions together simultaneously into a third vessel. Stir well.

2. Dilute the stock solutions as in (1). Pour the copper sulphate solution into the lime solution and stir well.

3. Dilute the stock solutions as in (1). Pour the lime solution into the copper sulphate solution and stir well.

4. Take 40 c.c. of copper sulphate and mix with 40 c.c. of lime. Then dilute to 500 c.c. with water and stir.

5. Mix up the same as in (4) and beat for 5 minutes with an egg beater.

6. Take 40 c.c. of copper sulphate and dilute to 460 c.c. Add 40 c.c. of lime and stir well.

7. Take 40 c.c. of lime and dilute to 460 c.c. Add 40 c.c. of copper sulphate and stir well.

When hydrated lime is used in place of stone lime, the field formula is expressed 4-6-50. Make a pint of stock solution using hydrated lime at the rate of 1 pound to 1 gallon. Make the following Bordeaux mixtures using the hydrated lime in place of stone lime.

8. Take 60 c.c. of lime and dilute to 250 c.c. Take 40 c.c. of copper sulphate solution and dilute to 250 c.c. Pour the two solutions together simultaneously into a third vessel and stir. Compare with (1).

9. Take 60 c.c. of lime and mix with 40 c.c. of copper sulphate. Then dilute to 500 c.c. with water and stir. Compare with (4).

10. Take 40 c.c. of copper sulphate and dilute to 440 c.c. Add 60 c.c. of lime and stir. Compare with (6).

The value of Bordeaux mixture as a fungicide was discovered by accident in the grape vineyards of southern France in 1878 by Millardet, a professor of botany at Bordeaux. He observed that where this spray solution was applied to ripening grapes for the purpose of checking theft, such vines suffered less from the destructive downy mildew.

At the present time Bordeaux mixture is one of the standard fungicides. There is evidence that in regions where apple blotch and bitter rot are prevalent its application gives more complete control of these diseases than any other known fungicide. In the heat of summer, spraying with Bordeaux probably causes less injury to fruit and foliage than applying one degree lime sulphur. On the other hand, cool, damp weather favors Bordeaux injury, as, for example, when applied to control apple scab in the first and second summer sprays.

There are various formulas for making Bordeaux mixture depending upon the plants to be sprayed and the diseases to be

controlled. When spraying potatoes for blight the usual strength is 5-5-50 or 6-6-50. For spraying apples the mixture should not be stronger than 4-4-50. On the more tender plants, as Japanese plums and peaches, the 2-4-50 formula should be used. The usual strength for truck crops in general is 3-6-50.

The value of Bordeaux mixture as a spray is determined by the amount of copper present, its ability to cover the surface of the plant, and its adhesiveness. These important qualities depend upon using the proper amounts of each ingredient and upon proper mixing. The copper is the active ingredient which controls the fungous diseases. The lime causes the formation of a compound which does not injure the foliage and which spreads and adheres well. When solutions of copper sulphate and calcium hydroxide are brought together a series of basic copper sulphates are precipitated. When properly mixed the precipitate remains in suspension for several hours, otherwise it settles rapidly.

Bordeaux mixture should always be tested in order to be sure that there is no copper in solution. One method of testing in the field is to insert a clean, polished knife blade in the spray. If no copper is deposited the spray is safe. Another and more reliable test is to allow a drop or two of potassium ferrocyanide solution to fall in the mixture. If the drop remains yellow in color, the mixture is safe, but if a brownish precipitate appears, more lime is needed to combine with the copper sulphate.

Besides being the most common and most efficient of all fungicides, it serves also as a repellant for certain flea beetles and leaf hoppers attacking vegetable crops.

Ordinary Bordeaux mixture will break down on standing any length of time. The addition of one-half pound of sugar to 50 gallons of spray will preserve it indefinitely.

A method of mixing on a commercial scale in the field may be found under the discussion of Bordeaux tank mixing, Ex. 55.

Notes:

Compare each of the samples of Bordeaux mixture as to amount of settling, color, size of precipitate, etc. Shake each cylinder well and compare again to see if these properties are fixed. How does hydrated lime compare with stone lime? Which is the best method of mixing and which is the poorest? Take a drop each of the best and poorest spray mixtures and examine

under the microscope. Can you formulate a method of distinguishing the poorest from the best mixture by describing the appearance of each under the microscope? Mass. Bul. 201, p. 23.

1. What is the physical nature of the compound formed when solutions of copper sulphate and lime are mixed? Vt. Bul. 196, p. 6.

2. What effect does the amount of lime particles enclosed in the precipitate have upon the rate of settling? Vt. Bul. 196, p. 7.

3. What are the effects of vigorous stirring upon Bordeaux mixture? Vt. Bul. 196, p. 8.

4. What physical change takes place when Bordeaux mixture stands for several days? Vt. Bul. 196, p. 11.

5. What change takes place before the copper in the Bordeaux mixture is effective in killing fungi? How is this done? Mass. Bul. 201, p. 23.

6. How does Bordeaux mixture cause injury to the plant? Mass. Bul. 201, p. 23.

7. What are the five qualifications of a good fungicide? Mass. Bul. 201, p. 21.

8. What is the cost of making 50 gallons of spray?

References:

— Tenn. Bul. Vol. 15, No. 2, 1902.

— Jour. Physical Chem., 11, p. 632, 1907.

— Illinois Bul. 135, 1909.

— Phytopathology, Vol. 4, p. 125, 1914.

— Vermont Bul. 196, 1916.

— Wisconsin Bul. 334, 1921.

— Massachusetts Bul. 201, 1921.

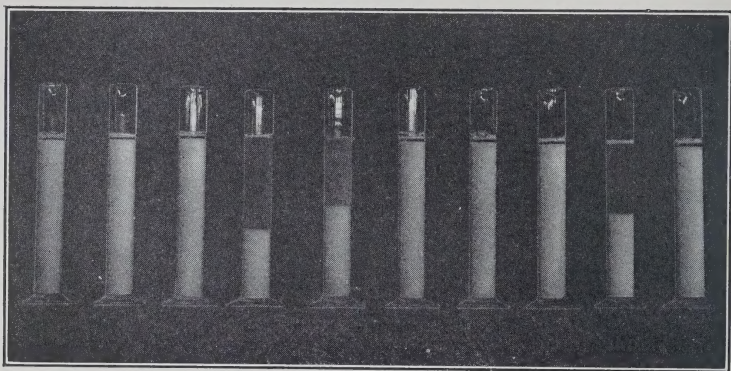


FIG. 3.—Samples of Bordeaux Mixture Prepared According to Exercise No. 27, after Standing Fifteen Minutes.

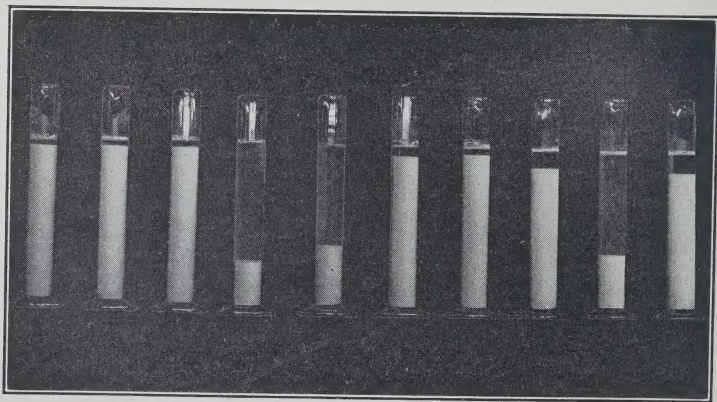


FIG. 4.—Same as Fig. 3 after Standing Thirty Minutes.

EXERCISE NO. 28

PICKERING SPRAY

Field Formula:

Copper sulphate	2½ lbs.
Stone lime	2 lbs.
Water	50 gals.

Directions:

Dissolve the copper sulphate in 2½ gallons of water. Where much spraying is done prepare a stock solution at the rate of 1 pound to 1 gallon. Place the lime in a container and slake with a little water. When a smooth paste has been formed add water to make 50 gallons. Stir six or eight times, allowing the insoluble particles to settle out between each stirring. After allowing it to settle out, draw off the clear limewater into the spray tank, add the copper sulphate solution and water to make 50 gallons of spray.

Make up 1 gallon of spray using stone lime and another gallon using 3 pounds of hydrated lime in place of 2 pounds of stone lime.

The only difference between the Pickering spray and Bordeaux mixture is in the making of the lime solution. Experiments have shown that Pickering sprays are about twice as effective as Bordeaux per unit of the copper present. It has been found that Pickering sprays containing .6 to .7 per cent of copper sulphate are just as effective for the spraying of potatoes as the 5-5-50 Bordeaux which contains 1.25 per cent copper sulphate. The theory advanced is that the copper in the Pickering spray is more readily available for fungicidal action than the copper in Bordeaux mixture due to the excess of lime in the latter. The Pickering sprays cannot be used on tender foliage. In experiments they have proved to be too caustic for apples and grapes.

Notes:

Describe the physical properties of the finished spray. How does it compare with Bordeaux mixture in appearance, and rate

of settling? Compare the use of hydrated lime with stone lime for making these sprays. Test both samples for free copper sulphate with potassium ferrocyanide and report in your notes.

1. What is the per cent of copper sulphate contained in a spray made by the above formula?
2. What is the cost of making 50 gallons of spray?
3. How does it compare in cost with ordinary Bordeaux mixture?

Reference:

U. S. D. A. Bul. 866, 1920.

EXERCISE NO. 29

SODA BORDEAUX MIXTURE

Field Formula:

Copper sulphate.....	4 lbs.
Caustic soda (slightly in excess so mixture is alkaline) about.....	1½ lbs.
Water.....	50 gals.

Directions:

Dissolve the copper sulphate in water and dilute to almost 50 gallons. Dissolve the caustic soda in a convenient amount of water. Add the soda solution to the copper sulphate solution until the mixture is just alkaline. Add water to make the volume 50 gallons. Make up $\frac{1}{2}$ gallon of spray in laboratory and set a cylinder full aside for observation.

This spray does not leave a stain on the fruit and foliage and therefore is used in place of Bordeaux mixture for spraying foliage plants and fruit or vegetables nearing maturity. It serves the same purpose as ammoniacal copper carbonate. Four-fifths of the deposit visible after spraying with Bordeaux mixture is due to the lime.

Soda Bordeaux is easier to apply than ordinary Bordeaux because there is no sediment to clog the nozzles.

Notes:

Describe the physical properties of the finished spray. Compare with ordinary Bordeaux mixture and with Pickering spray. Note the rate of settling at the end of 5, 10 and 15 minutes.

1. What is the cost of making 50 gallons?
2. How does it compare in cost with Bordeaux mixture?

References:

Stevens and Hall, Diseases of Economic Plants, 1910.
Ohio Bul. 309, 1917.

EXERCISE NO. 30

BORDEAUX MIXTURE AND STICKERS

BORDEAUX MIXTURE AND IRON HYDROXIDE

Field Formula:

Copper sulphate	4 lbs.
Iron sulphate	4 lbs.
Stone lime	8 lbs.
Water	50 gals.

Directions:

Dissolve the copper sulphate and iron sulphate either together or separately in water at the rate of 1 pound to a gallon. Slake the lime and add water to make 8 gallons of lime solution. Dilute the copper sulphate and iron sulphate solution to 42 gallons, then add the lime solution and stir. If hydrated lime is used, it will require 12 pounds. Make up $\frac{1}{2}$ gallon of this spray in laboratory and set a cylinder of it aside for observation.

This spray is useful on fruits and vegetables with smooth leaves. The iron sulphate is precipitated by the lime as iron hydroxide which is a colloid and serves as a sticker. The iron in this spray has no value as a fungicide. When a weaker spray is desired for more tender foliage, the amounts of copper sulphate, iron sulphate and lime may be reduced in proportion.

BORDEAUX MIXTURE AND RESIN FISH-OIL SOAP

Field Formula:

Resin fish-oil soap	2 or 3 lbs.
Bordeaux mixture	50 gals.

Directions:

Dissolve the required amount of the soap in water adding small amounts at a time and stirring well until the soap is dissolved.

Then add the soap solution to the Bordeaux mixture. Make up $\frac{1}{2}$ gallon of this spray in laboratory and set a cylinder of it aside for observation.

Resin fish-oil soap is often used with Bordeaux for spraying truck crops to increase the spreading and sticking qualities, especially those crops with smooth leaves as cabbage and onions.

BORDEAUX MIXTURE AND RESIN STICKER

Field Formula:

Resin sticker	1 gal.
Bordeaux mixture	50 gals.

Directions:

The resin sticker is prepared by mixing 2 pounds of pulverized resin, 1 pound of sal soda, and 1 gallon of water. Then boil this mixture from 1 to $1\frac{1}{2}$ hours or until the solution is a clear brown color. These amounts are sufficient for 50 gallons of spray. Make up $\frac{1}{2}$ gallon of Bordeaux mixture and add the proper amount of the resin sticker furnished in laboratory. Set a cylinder sample aside for observation.

This spray is used to some extent for spraying certain smooth-leaved truck crops as cabbage and onions but the resin fish-oil soaps are used more extensively.

Notes:

Describe the physical properties of each of the sprays made up. Compare them with each other and also with ordinary Bordeaux mixture. Describe the properties of the resin fish-oil soap and of the resin sticker.

1. What effect does soap have on Bordeaux mixture? Mass. Bul. 201.

2. What is the cost of making 50 gallons of Bordeaux mixture with each of the above stickers?

References:

- Ohio Bul. 309, 1917.
- Farmers' Bul. 856, 1917.
- Farmers' Bul. 908, 1918.
- Mass. Bul. 201, 1921.

EXERCISE NO. 31

SELF-BOILED LIME SULPHUR

Field Formula:

Flour of sulphur	8 lbs.
Stone lime	8 lbs.
Water	50 gals.

Directions:

Place the lime in a receptacle and add sufficient water to cover it. With poor lime hot water should be used to start the slaking. With good quick acting lime, cold water should be used or else the mixture is liable to get so hot as to bother the operator in mixing. While the lime is slaking sift in the sulphur. Stir the mixture constantly and add water from time to time until a thin even paste is secured. Do not allow it to get dry. If the action tends to become too vigorous add a little cold water.

With good limes, the boiling should be stopped when the lime is slaked, by adding cold water. Poor grades of lime are allowed more time to cook. The mixture should not be allowed to remain hot for any length of time as this results in the formation of too high a concentration of sulphides which will injure the foliage. The mixture should be run through a 20-mesh strainer in order to remove the coarse particles of lime. However, the sulphur should be worked through the strainer as it is the fungicidal agent. After diluting to the required amount it is ready for application.

Self-boiled lime sulphur is merely a mechanical mixture of lime and sulphur with a small amount of sulphides in solution. The constant stirring, high temperature and violent cooking results in a very uniform mixture of finely divided lime and sulphur particles. It is used in place of Bordeaux mixture and lime sulphur solution on certain stone fruits. It is the standard summer spray for peaches to control brown rot and scab. This spray is also used on Japanese plums in foliage. The larger the quantity made up at one time, the more effective will be the heat of the lime and the

better the results secured. About 200 gallons at a time is to be preferred.

Make 1 gallon of spray in laboratory and set a sample aside in a glass cylinder for observation.

Notes:

Describe the physical properties of the spray. Note the changes taking place during the mixing process. Note the rate of settling in 5, 10 and 15 minutes, and the color of the clear liquid.

1. Why should the mixture not be allowed to cook too vigorously?
2. Why should the coarse particles of lime be removed when pouring the mixture into the sprayer?
3. Why is self-boiled lime sulphur used in place of Bordeaux and lime sulphur solution on peaches? Mass. Bul. 201, p. 27.
4. What effect does the heat formed have on the particles of sulphur? Mass. Bul. 201, p. 28.
5. What is the cost of making 50 gallons of spray?

References:

- Farmers' Bul. 243, 1906.
- Virginia Bul. 210, 1916.
- U. S. D. A. Bul. 395, 1917.
- Ohio Bul. 309, 1917.

EXERCISE NO. 32

SELF-BOILED LIME SULPHUR (SUBSTITUTE)

Field Formula:

Flour of sulphur	8 lbs.
Hydrated lime	8 lbs.
Water	50 gals.

Directions:

Take the 8 pounds of sulphur and 8 pounds of hydrated lime and mix together dry. Pour over the mixture 8 gallons of boiling water and stir vigorously for 5 minutes. At the end of this time, cool with cold water. Then strain through a 20-mesh sieve and dilute to 50 gallons. In laboratory make up 1 gallon of spray and set a sample aside in a glass cylinder for observation.

This spray is practically the same as the ordinary self-boiled lime sulphur and is used for the same purposes. It should take the place of ordinary self-boiled lime sulphur in localities where it is difficult to secure good, fresh stone lime and also where it is impossible to keep the unslaked lime for any length of time.

Notes:

Describe the physical properties of the finished spray and compare with the ordinary self-boiled lime sulphur. Also compare them as to ease of mixing. Note the rate of settling at the end of 5, 10 and 15 minutes and compare with self-boiled lime sulphur.

1. Why would a good agitator be necessary when applying self-boiled lime sulphur?

2. Which of the two methods of making self-boiled lime sulphur do you prefer and why?

3. Is it safe to combine arsenicals or contact poisons with this spray?

4. What arsenicals cannot be used with this spray when spraying peaches?

5. What is the cost of making 50 gallons of this spray and how does it compare with the ordinary self-boiled lime sulphur?

References:

Virginia Bul. 210, 1916.

West Virginia Bul. 167, 1918.

Michigan Special Bul. 87, 1918.

Michigan Special Bul. 102, 1920.

EXERCISE NO. 33

WETTABLE SULPHURS OR SULPHUR PASTES

Field Formula:

Commercial sulphur paste	4 to 10 lbs.
Water	50 gals.

Directions:

Gradually thin the paste furnished in laboratory with a little water and then dilute to the required amount. Make up $\frac{1}{2}$ gallon of spray and set sample aside for observation.

Commercial sulphur pastes are offered to meet a demand for a satisfactory substitute for self-boiled lime sulphur. The fresh stone lime needed for the latter mixture is difficult to secure in some localities and cannot long be kept unslaked. Some growers having small plantings of peaches, Japanese plums, and other plants with tender foliage, are also glad to avoid the labor of making the self-boiled mixture and will buy the rather expensive sulphur pastes which mix so readily with water.

The fungicidal value of this mixture is much like that of dry sulphur. It is sometimes desirable to mix sulphur with water, but it is difficult to get a uniform mixture, for sulphur is not easily wetted with water. To overcome this difficulty dextrin, diatomaceous earth, flour, glue, oleic acid or soap may be added, and some of these materials are used in commercial brands of sulphur pastes. The literature of the day refers to this type of fungicide as a "wetable sulphur." Commercial brands usually contain 40 to 50 per cent of a very fine form of sulphur, the remainder of the mixture being water and one of the substances mentioned above.

HOMEMADE WETTABLE SULPHUR

Field Formula:

Powdered glue (ordinary ground glue)	$\frac{3}{8}$ ounce
Sulphur (flowers or powdered)	5 lbs.
Water to make	50 gals.

Directions:

Dissolve the glue in $\frac{3}{4}$ gallon of hot water. On the farm the glue may be soaked in cold water the night before and heated the next day until fully dissolved. Mix this solution with the sulphur a little at a time working out the lumps into as smooth a paste as possible. Rubbing gives better results than stirring. Then work this paste through a strainer with a 20-mesh screen using a stiff brush and adding the remainder of the glue solution. Add enough water to make 50 gallons. For best results the finest grades of sulphur such as are especially prepared for dusting should be used.

Notes:

Describe the pastes as they appear before and after mixing. Compare with self-boiled lime sulphur as to appearance, rate of settling and ease of mixing.

1. Are there any arsenicals or contact sprays which cannot be safely combined with sulphur pastes?
2. Under what conditions would it not be advisable to use Paris green or calcium arsenate with this spray?
3. What is the cost of making 50 gallons of spray?

References:

- Indiana Station Cir. 69, p. 19, 1917.
- U. S. D. A. Bul. 395, 1917.
- Mich. Spec. Bul. 87, 1918.
- Mich. Spec. Bul. 102, 1920.
- Cal. Cir. 227, p. 56, 1921.

EXERCISE NO. 34

STUDY OF COMMERCIAL SULPHUR PREPARATIONS

The purpose of this exercise is to familiarize the student with some of the commercial sulphur preparations found on the market. Some of these are proprietary mixtures and are recommended by the manufacturers to be as efficient as the standard lime sulphur concentrate.

PART I

Study all the preparations assigned and in your notes include the following data in tabular form:

Name	Manu- facturer	Analyses	Formula for 50 gals.		Cost of 50 gals.		Physical Properties
			Dor- mant	Sum- mer	Dor- mant	Sum- mer	

PART II

Make up $\frac{1}{2}$ gallon of spray mixture of each preparation studied. Where the same preparation is used for both dormant and summer spraying, make up two spray mixtures, one for dormant spraying and the other for summer spraying. Study all spray mixtures carefully, make the following observations, and indicate in tabular form:

Trade Name	Dormant or Summer	Amount for $\frac{1}{2}$ gallon	Degrees Bé.	Per Cent Sediment	Physical Properties	Pests Controlled

Finally write up some general conclusions drawn from your results and make some comparisons.

EXERCISE NO. 35

STUDY OF COMMERCIAL BORDEAUX PREPARATIONS

There are a number of commercial Bordeaux preparations on the market at the present time. Some contain arsenicals as lead arsenate or Paris green and will control chewing insects as well as fungous diseases. Various commercial brands will be studied in laboratory in order that the student may become familiar with them.

PART I

Take the following notes on the commercial mixtures assigned in laboratory and record in tabular form.

Name	Manufacturer	Paste or Powder	Analyses	50 gal. Formula	Pests Controlled

PART II

Make up $\frac{1}{2}$ gallon of spray mixture of each commercial preparation according to the formula on the package. Pour a sample of each in a glass cylinder for observation. Label each cylinder. Make the following observations and record in tabular form:

Name	Amount used for $\frac{1}{2}$ gal.	Color	Precipi- tate Quality	Amount of Settling in				Amount of Sedi- ment
				1 min.	5 min.	10 min.	15 min.	

Finally write up some conclusions drawn from the results secured and make comparisons. Also compare with homemade Bordeaux mixture.

EXERCISE NO. 36

TO DETERMINE VALUE OF COMMERCIAL BORDEAUX PREPARATIONS

The various commercial preparations of Bordeaux mixture and Bordeaux lead, vary greatly in strength in terms of the copper and the lead arsenate contained. The purpose of this exercise is to determine the relative values of these mixtures as compared with each other and also with the homemade Bordeaux mixture.

All information concerning these mixtures will be compiled in three tables. The first table will contain the data secured from the labels on the containers. To give the copper in terms of per cent of CuSO_4 it will be necessary to multiply the per cent of Cu by the factor 3.93. The selling price of the mixture will be given by the instructor.

TABLE I

Name	% Cu	% CuSO_4	% Dry Lead arsenate	Manuf. Formula for 50 gals.	Selling Price per lb.

The grower measures the strength of his homemade Bordeaux mixture in terms of the CuSO_4 contained in 50 gallons. In order to compare the commercial preparations with homemade Bordeaux it will be necessary to reduce them to the same basis. This information will be tabulated in Table II. This table will also indicate the relative costs of making up 50 gallons of spray according to manufacturers' formula and when made up to full strength.

TABLE II

Name	Lbs. CuSO ₄ in 50 gals.	Lbs. Dry Lead Arsenate in 50 gals.	Cost to make 50 gals. by Manuf. formula	Formula for 50 gals. con- ing 4 lbs. CuSO ₄	Cost of mak- ing 50 gals. containing 4 lbs CuSO ₄

In the third table will be tabulated the values of the various commercial preparations as determined by the market value of the CuSO₄ lime and lead arsenate contained. These values can then be compared with each other and also with the selling price of the preparation. The difference between value and price represents the manufacturers' cost of mixing, cost of handling, cost of marketing and profits.

TABLE III

Name	Lbs. CuSO ₄ in 100 lbs.	Lbs. Lime in 100 lbs.	Lbs. Dry Lead Arsenate in 100 lbs.	Value of CuSO ₄	Value of Lime	Value of Dry Lead Arsenate	Total Value	Selling Price

Other factors which determine the value of the commercial preparations as compared with the homemade Bordeaux mixture and which are not considered in this exercise, are cost of labor

and equipment for mixing and also their physical properties. The texture and adhesive qualities of a mixture are equally as important as the amount of Cu contained.

The question may arise whether the weaker strengths of Bordeaux will be satisfactory. Where the disease infection is very mild, the weaker strengths will give good control. In case of more severe infection the control will only be partial although some benefit will be derived. For the stone fruits, the weaker strengths of Bordeaux mixture 2-3-50 or 2-4-50 are necessary. The 4-4-50 or 4-6-50 formula has usually been recommended for control of apple blotch in the Middle West. Demonstrations now under way in Indiana indicate that a 3-5-50 Bordeaux mixture thoroughly applied will control blotch with considerably less burning to fruit and foliage.

Write up your notes neatly and correctly. Give conclusions and note any interesting comparisons which may come to your attention.

References:

- Farmers' Bul. 994, 1918.
- Mass. Bul. 201, 1921.

COMBINATION SPRAYS

EXERCISE NO. 37

BORDEAUX AND PARIS GREEN

Field Formula:

Paris green	$\frac{1}{2}$ lb.
Bordeaux mixture	50 gals.

Directions:

Before pouring the solutions of lime and copper sulphate together for making the Bordeaux mixture, take the Paris green and mix it into a thin paste with a little of the lime solution. Then mix this paste with the remaining solution and make the Bordeaux mixture in the usual way. Make up 1 gallon of this spray and set a sample aside for observation.

This spray is used for the control of fungous diseases and chewing insects on plants having foliage not subject to injury from Paris green.

Notes:

Describe the physical properties of the spray and compare with the combined Bordeaux and lead arsenate spray. Note rate of settling.

1. Give three advantages of lead arsenate over Paris green. Purdue Ext. Bul. 80 or Farm. Bul. 908, p. 8.
2. Does this combination have a greater fungicidal value than when Bordeaux is used alone? Mass. Bul. 201, p. 31.
3. What beneficial effect does Bordeaux have on Paris green? Mass. Bul. 201, p. 31.
4. What is the cost of making 50 gallons of spray?

EXERCISE NO. 38

BORDEAUX AND ARSENATE OF LEAD

Field Formula:

Lead arsenate (dry)	1 to 1½ lbs.
Bordeaux mixture	50 gals.

Directions:

First mix up the Bordeaux mixture and then add the dry lead arsenate slowly, at the same time stirring vigorously. Make up $\frac{1}{2}$ gallon of this spray in laboratory and set a cylinder full aside for observation.

This spray is used for the control of fungous diseases and chewing insects on plants where Bordeaux mixture is the usual fungicide.

Notes:

Describe the physical properties of the spray. Note the rate of settling.

1. Name all the pests controlled by this spray when applied as the third summer spray on apples. Purdue Ext. Bul. 80 or Farm. Bul. 908, p. 83.

2. What conditions may result when sprays are combined? Mass. Bul. 201, p. 30.

3. What is the cost of making 50 gallons of spray?

EXERCISE NO. 39

BORDEAUX AND NICOTINE SULPHATE

Field Formula:

Nicotine sulphate	$\frac{1}{2}$ pt.
Bordeaux mixture	50 gals.

Directions:

First mix up the Bordeaux mixture in the usual manner. Then add the nicotine sulphate and stir thoroughly. Make up $\frac{1}{2}$ gallon of spray in laboratory and set a cylinder full aside for observation. (473 c.c. = 1 pt.)

This spray is used for the control of fungous diseases and sucking insects on certain vegetable crops such as tomatoes, not seriously troubled with chewing insects. It is also used on cucumbers, as the arsenate of lead does not control the striped cucumber beetle while the Bordeaux mixture serves to repel the insect. It is advisable to spray vegetable crops for aphids as a protective measure, because the aphids are known to transmit mosaic.

Notes:

Describe the physical properties of the spray. Compare with ordinary Bordeaux mixture.

1. What insects and diseases are controlled by this spray?
2. Would it be advisable to use kerosene emulsion instead of nicotine sulphate with Bordeaux mixture?
3. Is it advisable to use soap with this spray to increase its sticking and spreading qualities? Mass. Bul. 201, p. 12.
4. What is the cost of making 50 gallons of spray?

EXERCISE NO. 40

BORDEAUX, LEAD ARSENATE AND NICOTINE SULPHATE

Field Formula:

Lead arsenate (dry)	$\frac{1}{2}$ lb.
Nicotine sulphate.....	$\frac{1}{2}$ pt.
Bordeaux mixture	50 gals.

Directions:

Prepare the Bordeaux mixture in the usual way. Then add the dry lead arsenate slowly while stirring the spray. Finally add the nicotine sulphate and stir thoroughly. Make up $\frac{1}{2}$ gallon of this spray in laboratory and set a sample aside in a glass cylinder for observation.

This is one of the two most useful combination sprays. The other contains lime sulphur in place of Bordeaux. This combination contains standard materials used in the control of the three main types of pests, namely, fungous diseases, chewing and sucking insects. The Bordeaux mixture in this combination is prepared at varying strengths (see Ex. No. 27), and when this fungicide is made sufficiently weak, it may be used as a substitute mixture for self-boiled lime sulphur in the control of diseases on plants having tender leaves, such as the stone fruits. At standard strengths (4-4-50 or 4-6-50) it is used for controlling the most persistent diseases, such as apple blotch and bitter rot. Since Bordeaux is also the standard fungicide for potato and other vegetable diseases, this combination spray has a wider range of usefulness than the one containing lime sulphur.

Notes:

Describe the physical properties of the spray and compare with ordinary Bordeaux mixture. Note the rate of settling.

1. What pests in general are controlled by this spray?
2. Can this spray be used on all plants? If not, what are the exceptions?
3. What is the cost of making 50 gallons of spray?

EXERCISE NO. 41

LIME SULPHUR AND IRON SULPHATE

Field Formula:

Iron sulphate.....	3 lbs.
1 deg. Bé. lime sulphur.....	50 gals.

Directions:

Fill a glass cylinder about three-fourths full with the concentrated lime sulphur to be used and test with a hydrometer. From the lime sulphur dilution table compute the amount of dilution necessary. Dissolve the iron sulphate in the diluted lime sulphur solution using a small amount of liquid to dissolve the salt and then adding this mixture to the remaining solution. Where a great deal of spraying is done it might be more convenient to make a stock solution of iron sulphate at the rate of 1 pound to 1 gallon. Make up $\frac{1}{2}$ gallon of 1 degree Bé. lime sulphur spray and also $\frac{1}{2}$ gallon consisting of 1 degree Bé. lime sulphur and iron sulphate. Set samples of each aside in glass cylinders for observation.

The purpose of adding the iron sulphate to the lime sulphur spray is to reduce the burning and increase the adhesiveness of the latter. Iron sulphide is formed and is supposed to have some fungicidal effect. The use of iron sulphate alone as a fungicide is very limited. Copper salts are more efficient than iron salts in this respect.

Iron sulphate solution is sometimes used, however, on dormant grape vines for the control of anthracnose. The strength used for this purpose is 100 parts concentrated iron sulphate solution and 1 part sulphuric acid. This solution is very caustic and is applied with a swab. However, the 5-degree lime sulphur solution is also effective as a dormant spray for grapes and easier to apply.

Notes:

Describe the physical properties of the 1-degree lime sulphur and iron sulphate spray. Compare with 1-degree Bé. lime sulphur spray.

1. Discuss the changes which take place when the lime sulphur on the foliage is exposed to the air and name the substances which are toxic to fungi. Mass. Bul. 201, p. 26.

2. Why has the use of Bordeaux mixture in orchard spraying been largely replaced by lime sulphur? Mass. Bul. 201, p. 27.

3. Under what conditions is it advisable to use Bordeaux mixture for spraying apples? Purdue Ext. Bul. 80 or Farm. Bul. 908, p. 83.

4. What is the cost of making 50 gallons of spray?

References:

Hesler & Whetzel, Manual of Fruit Diseases.

EXERCISE NO. 42

LIME SULPHUR AND LEAD ARSENATE

Field Formula:

Lead arsenate (dry)	1 to 1½ lbs.
1 deg. Bé. lime sulphur	50 gals.

Directions:

Test the concentrated lime sulphur with a hydrometer and compute the amount of dilution from the dilution table. Dilute the lime sulphur. Then add the dry lead arsenate slowly while stirring the lime sulphur solution. The lead arsenate may be first made into a thin paste with a little water and then added to the lime sulphur. Make up $\frac{1}{2}$ gallon in laboratory and set a sample aside for observation.

Lime sulphur is very useful in the spraying of fruits but in general is not desirable for spraying vegetable crops. Experiments have shown that potatoes are injured by spraying with lime sulphur. The addition of the lead arsenate besides serving as a poison for chewing insects, increases the efficiency of the lime sulphur as a fungicide and increases the adhesive qualities.

When lime sulphur and acid lead arsenate are mixed together, some decomposition takes place and the black precipitate, lead sulphide, is formed, which drops to the bottom of the tank. Arsenic in the lead arsenate is rendered soluble and this causes the burning of foliage which often follows the application of this combination spray. The insecticidal value of arsenate of lead is also measurably decreased in the spray.

Experiments at Oregon in 1919 covering the chemical nature of these reactions evolved the recommendation that 5 pounds of lime should be added to 50 gallons of spray. This checked the breakdown of the spray materially, maintained the efficiency of the insecticide, and reduced foliage injury.

Laboratory tests in the mixing of these ingredients performed

at Massachusetts showed that "if the milk of lime and lead arsenate were mixed together and then poured into the diluted lime sulphur, much better protection against breakdown and burning of foliage was afforded than if the two were added separately. In this case the protective agent was present when the two active ingredients of the spray were brought together."

Mixtures prepared in this way were applied in the orchards of the Department of Pomology at Massachusetts Agricultural College, and were compared with the old method. The results showed the new method of mixing superior in the following ways:¹

1. "The physical nature of the spray was improved.
2. "There was very little sediment left in the bottom of the tank after spraying, consequently it was not necessary to clean out the tank thoroughly before each refilling. This meant a considerable saving of time in the course of a day's spraying.
3. "There was no blackening of the men or equipment, a very objectionable feature of the old method.
4. "The spray was fully as easy to prepare by this method and required no more time.
5. "Most important, no burning was noted with this spray."

Notes:

Describe the physical properties of the spray. Note the changes which take place upon the addition of the lead arsenate to the lime sulphur.

1. Would it be desirable to replace the lead arsenate with Paris green in this spray?
2. Should lead arsenate ever be combined with sodium or potassium sulphide sprays?
3. What pests in general are controlled by this spray?
4. How may acid lead arsenate be combined with lime sulphur to make a safe spray? Mass. Bul. 201, p. 32.
5. What is the cost of making 50 gallons of spray?

References:

- Cornell Bul. 289.
- Farmers' Bul. 856.
- Hesler and Whetzel, Manual of Fruit Diseases.

¹ Bourne, A. I., "Improved Lime Sulphur, Lead, Arsenate, Milk of Lime Spray," American Fruit Grower, March, 1922.

EXERCISE NO. 43

LIME SULPHUR, LEAD ARSENATE AND NICOTINE SULPHATE

Field Formula:

Lead arsenate (dry)	1 to 1½ lbs.
Nicotine sulphate	½ pt.
1 deg. Bé. lime sulphur	50 gals.

Directions:

First test the concentrated lime sulphur and compute the amount of dilution from the dilution table. Prepare the dilute lime sulphur spray and add the dry lead arsenate slowly while stirring. Then add the nicotine sulphate and stir. Make ½ gallon of this spray in laboratory and set a sample aside for observation.

This combination ranks second to the Bordeaux-lead arsenate-nicotine sulphate mixture in range of usefulness.

Lime sulphur is easier to prepare than Bordeaux, hence it is preferred when it may be used with safety. The fungicide applied in the first two summer sprays for apples and pears is usually lime sulphur in all commercial regions of the United States. In the northern sections, the later fungicidal applications may also be lime sulphur, but in districts farther south, growers usually prefer Bordeaux mixture because they seem to get less spray injury on the fruit and foliage, and more effective control of apple blotch and bitter rot, during this period when the weather is hottest. In northern regions Bordeaux frequently produces spray burn on fruit and foliage, also what is known as russetting of the fruit. The greater injury here has been explained as due to lower temperatures, and in certain instances to greater rainfall and humidity.

Growers of peaches and other stone fruits sometimes use lime sulphur diluted to strengths varying all the way from 1 to 50 to 1 to 100. They prefer to use it, and will accept the risk of causing spray injury, rather than perform the tedious work of mixing self-boiled lime sulphur, or assume the added expense of buying com-

mercial sulphur pastes or wettable sulphurs. A few growers are fairly successful in using lime sulphur for stone fruits, but its use for this purpose is not to be recommended, because the results are too variable even where reasonable care and judgment are exercised.

A recent investigation which considered the toxicity of sulphur fungicides numbers among its conclusions the following statements:

"Sulphur is fungicidal when oxygen is present, but not when oxygen is absent."

"The toxicity of sulphur to fungi increases with rise of temperature and length of time of exposure."

"Fungi differ in their susceptibility to the toxic action of sulphur."

"Commercial lime sulphur solution at dilutions of one part in forty parts of water or of one part in ten parts of water, does not prevent germination of the conidia of scab, when sulphides are absent."

These facts partially explain the puzzling differences which occur in actual spray work.

Notes:

Describe the physical properties of the spray and compare with the other lime sulphur sprays.

1. Under what conditions is it not necessary to use nicotine sulphate in the summer sprays for apples? Purdue Ext. Bul. 80 or Farm. Bul. 908, p. 83.

2. What pests are controlled by this spray if applied on apples before the blossoms open and after the leaf buds open? Purdue Ext. Bul. 80 or Farm. Bul. 908, p. 83.

3. Could kerosene emulsion be used in this spray instead of nicotine sulphate for the control of aphids?

4. What is the cost of making 50 gallons of spray?

¹ Doran W. L., N. H. Tech. Bull. 19, 1922, "Toxicity of Some Sulphur Fungicides."

MISCELLANEOUS

EXERCISE NO. 44

CORROSIVE SUBLIMATE

Field Formula:

Corrosive sublimate.....	4 oz.
Water.....	30 gals.

Directions:

Dissolve the corrosive sublimate in a small amount of hot water and add to the remaining water. The corrosive sublimate will dissolve in cold water if an equal amount of ammonium chloride is dissolved with it. This formula is equal to the strength of 1 part to 1000 parts. Make up 1 gallon of this solution in laboratory and set a sample aside in a glass cylinder for observation.

This solution is used for the treatment of seed potatoes for the control of scab, black leg and rhizoctonia, for the treatment of cabbage seed to control black leg and black rot, and also to disinfect pruning tools when cutting out diseases such as fire blight. It is a fungicide but is so caustic to foliage that it cannot be used as a spray on plants.

Cabbage seed is soaked in this solution 20 minutes, washed with fresh water and allowed to dry or is planted at once.

Cucumber seed is soaked in this solution for 5 minutes and then washed for 15 minutes to control angular leaf spot. Tomato seed is soaked in a 1 to 3000 solution for 5 minutes and washed for 15 minutes to control bacterial leaf spot. The solution should be made up fresh for each lot of seed treated.

Corrosive sublimate is effective against cabbage and radish maggots. Make two or three applications of the solution to the plants at intervals of 10 days after the flies deposit eggs. It is effective as a stomach and contact poison. Carbolic acid emulsion was formerly recommended for the control of root maggots, but because it is less effective, its use has been largely discontinued.

Mercuric cyanide solution 1 to 500 is used to treat wounds when cutting out fire blight.

Use only wooden, earthenware or glass vessels for handling this solution as it will corrode metal containers. Handle with care as it is a *deadly poison*. Corrosive sublimate is precipitated by organic matter and therefore a fresh solution should be made for each seed treatment or the strength maintained by additions of corrosive sublimate, as in the treatment of seed potatoes.

Notes:

Describe the physical properties of the powder and of the solution.

1. How long should potatoes be left to soak in this solution? Wis. Bul. 331 or Purdue Ext. Bul. 64.

2. How should the strength of the solution be maintained when treating seed potatoes? Wis. Bul. 331 or Purdue Ext. Bul. 64.

3. Why should potatoes to be green sprouted be treated before sprouting? Purdue Ext. Bul. 64 or Wis. Bul. 331.

4. What is the cost of making 30 gallons of solution?

References:

Farmers' Bul. 856, 1917.

Wisconsin Bul. 331, 1921.

Purdue Bul. 251, 1921.

Purdue Exten. Leaflet 123, 1921.

EXERCISE NO. 45

FORMALDEHYDE

Field Formula:

Formaldehyde (40%)	1 pt.
Water	30 gals.

Directions:

Add the formaldehyde to the water and stir. Make up 1 gallon of this solution in laboratory and set a sample aside for observation. (473 c.c. = 1 pt.)

This solution is used for the treatment of seed potatoes for scab, for the control of black rot and black leg of cabbage, for oat smut, for onion smut and for drenching the soil to control certain diseases.

For soil sterilization it is usually made up twice as strong and applied at the rate of 1 gallon to each cubic foot of soil.

The dry method of treating oats for smut is often used. By this method the formaldehyde is diluted 1 to 1 and a quart of this solution is used for each bushel of seed. The solution is sprayed on the seed as it is shoveled on a pile which is then covered with sacks or canvas for 5 hours. The seed may be planted immediately after treatment.

Formaldehyde is also known as formalin, which is a trade name. It is a solution of formaldehyde gas in water. It is not poisonous.

Notes:

Describe the physical properties of the formaldehyde before and after diluting.

1. In what way does formaldehyde kill fungi and bacteria? Mass. Bul. 201, p. 29.

2. How long are seed potatoes left to soak in this solution? Wis. Bul. 331 or Purdue Ext. Bul. 89.

3. What are the advantages of formaldehyde over corrosive sublimate for the treatment of seed potatoes? Wis. Bul. 331 or Purdue Ext. Bul. 89.

4. What is the disadvantage? Wis. Bul. 331 or Purdue Ext. Bul. 89.

5. What is the cost of making 30 gallons of solution?

References:

Farmers' Bul. 856, 1917.

Farmers' Bul. 1060, 1919.

Iowa Research Bul. 59, 1920.

Wisconsin Bul. 331, 1921.

Massachusetts Bul. 201, 1921.

EXERCISE NO. 46

IRON SULPHATE

Field Formula:

Iron sulphate	2 lbs.
Water	1 gal.

Directions:

Dissolve the iron sulphate in the water. Make up $\frac{1}{2}$ pint of this solution in laboratory and set a sample aside in a glass cylinder for observation.

This solution is used to control weeds as wild mustard, red sorrel, chickweed, cocklebur, rag weed, dandelion, daisies, wild lettuce, etc. It is used quite extensively for the control of wild mustard in grain fields and for red sorrel in timothy meadows. The weeds should be sprayed before they reach the blooming period. It does not permanently injure the main crop, but may cause blackening of the leaves for a few days. The solution should be sprayed on a warm, calm day with no indication of rain for at least 24 hours. One acre will require 50 gallons.

Running weeds as chickweed and moneywort in lawns may be eradicated by an application of nitrate of soda. The application should be heavy enough to kill the weeds. Some of the grass will be killed but it will be replaced by a good growth of grass to the exclusion of the weeds.

When iron sulphate is the control method for killing dandelions in lawns about four or five applications should be made during the season. The first application is made when the blossom buds are formed but before they open. This should be followed by one or two more sprays at intervals of 3 or 4 weeks. Do not spray in hot, dry weather. Make one or two more sprayings in late summer or fall.

Notes:

Describe the physical properties of the iron sulphate before and after dissolving in water.

1. Has iron sulphate any value as a fungicide?
2. What will the cost of materials be for spraying 1 acre?

References:

New York (Geneva) Bul. 466, 1919.

EXERCISE NO. 47

ARSENATE OF SODA

Field Formula:

Arsenate of soda	2 lbs.
Water	10 gals.

Directions:

Dissolve the arsenate of soda in the water. Make up 1 quart of this solution in laboratory and set a sample aside in a glass cylinder for observation.

This solution is very useful for the control of weeds on tennis courts, gravel walks, drives, etc. The amount made by the above formula will treat an area 1 rod square and can be applied with a watering can or a spray outfit. This solution is also used to kill ivy on trees, stonewalls and buildings. Two or three applications should be sufficient. When it is desired to kill trees, holes are bored into the trunk, arsenate of soda put in and the holes plugged with corks. The advantage of this method is that it prevents sprouting from the stump.

This substance is very poisonous and should be handled with care. Do not apply too freely near valuable trees.

Prepared brands of weed killers containing arsenate of soda and arsenite of soda may be purchased and used effectively. Commercial brands of both weed killers are rather expensive.

Notes:

Describe the arsenate of soda before and after dissolving in water.

1. Would you recommend the use of arsenate of soda at some weaker strength as a poison insecticide on plants? Why?
2. What is the cost of making 10 gallons of solution for weed control?

Reference:

Mass. Bul. 123, 1908.

EXERCISE NO. 48

MATERIALS APPLIED AS DUSTS

The purpose of this exercise is to get acquainted with the various ingredients available in laboratory which are applied in dust form for the control of insects and plant diseases.

The dust materials now found on the market include sulphur, copper lime, copper soap, arsenate of lead, calcium arsenate, and nicotine sulphate. The fillers or carriers used are land plaster, hydrated lime, calcium oxide, infusorial earth, kaolin, and kieselguhr.

Notes:

Examine the dusts on display, and make a record of the name and brand, also the comparative degree of fineness and weight of these dusts.

1. In what proportions are the various ingredients or materials assembled?

2. For what purposes may nicotine sulphate and sulphur dust be mixed together? U. S. D. A. Circ. 154, p. 14.

3. What are the advantages and disadvantages of nicotine sulphate dust? U. S. D. A. Circ. 154, p. 15.

4. For what purposes may calcium arsenate be used to better advantage as a dust than arsenate of lead? 1920 Yearbook, U. S. D. A. Separate No. 842.

5. Compare the various fillers as to availability, fineness, weight, etc. (See Chapter VI on Dusting.)

6. For what purposes is copper lime dust considered promising? (See Chapter VI on Dusting.)

References:

Calcium arsenate:

Coad, B. R., Experimental Work on Poisoning Cotton Boll Weevils, U. D. S. A. Bul. 731, 1918. Coad, B. R., and Cassidy, T. P., Rules for Poisoning the Cotton Boll Weevil, U. S. D. A. Circ. 162, 1921. Hunter,

W. D., and Coad, B. R., The Boll Weevil Problem, Farmers' Bul. 1262, 1922.

Nicotine Sulphate:

Holland, E. B., Bourne, A. I., and Anderson, P. J., Insecticides and Fungicides, Mass. Bul. 201, 1921. Parrott, P. J., Glasgow, Hugh, and MacLeod, G. F., Control of Apple Red Bugs by Dusting, Geneva (N. Y.) Bul. 490, 1921. Zimmerley, H. H., Geise, F. W., and Willey, C. R., Dusting Vegetable Crops, Virginia Truck Exp. Sta. Buls. 35 and 36.

Various Dusts:

Journal of Econ. Ent., Vol. 14, No. 2, 1921, pp. 206-238.

EXERCISE NO. 49

FIELD COOKING OF LIME SULPHUR

Field Formula:

Stone lime (90% CaO)	40 lbs.
Sulphur	80 lbs.
Water	50 gals.

The amount of lime used is figured on a basis of 36 pounds pure calcium oxide which is the exact amount required for the above formula. Use freshly burned stone lime. The finely ground commercial sulphur or the flowers of sulphur may be used.

Directions:

The lime sulphur concentrate may be made in large iron kettles over a fire or cooked with steam in either wooden or iron vessels. A small boiler supplying live steam at a pressure of from 10 to 20 pounds is necessary for steam cooking.

To make the above formula, place about 10 gallons of water in the cooking vessel and start the fire or turn on the steam. Weigh out the necessary materials. Add the stone lime. When the slaking begins add the sulphur either by sifting the dry form or adding it as a thin paste. Keep stirring the materials while the slaking is going on. Add water as it is required until the lime is slaked.

If cooking by fire, bring the contents up to 55 gallons and boil for about 1 hour. When steam is used the cooker need only be filled to the 50-gallon mark since the condensation of the steam equalizes the amount of water lost through evaporation. When cooking ceases, the concentrated lime sulphur should measure 50 gallons. During the boiling the mixture should be stirred frequently. If cooked with steam, the escaping steam will help to keep the mixture agitated.

The concentrate should be stored in barrels or other tight containers which are well stoppered. Be sure to fill completely

so as not to leave any air space. Before pouring into the barrel, the solution should be strained with a 30 to 50-mesh strainer to remove coarse particles. If a container is not filled completely full, the lime sulphur should be covered over with a layer of heavy oil or paraffin to exclude the air.

References:

Pennsylvania Bul. 115, 1912.

Virginia Bul. 201, 1913.

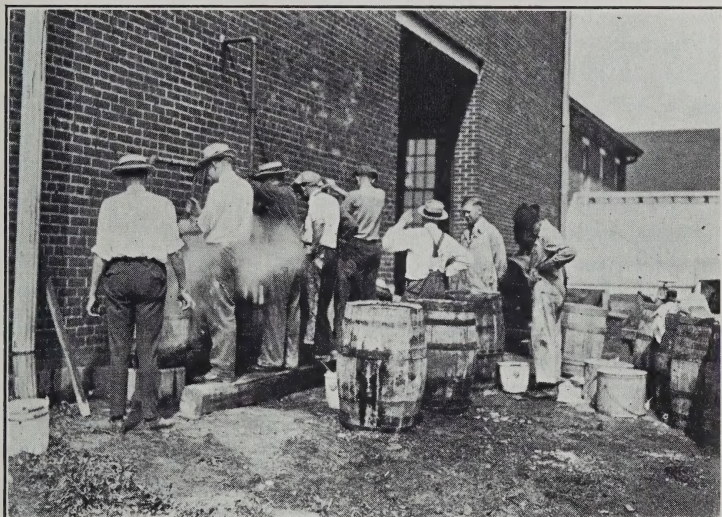


FIG. 5.—Students Making Lime Sulphur Solution using Steam as the Source of Heat.

EXERCISE NO. 50

ORDINARY WHITEWASH

VALUE OF WHITEWASH

The value of whitewash as a spray material may be a debatable question, but it has been recommended for application to fruit trees to prevent early budding, and as a deterrent of the root borer¹ and the shot-hole borer, on cherries.² However lightly we may rate its value for these purposes, nearly everyone recognizes its great value when applied like paint to greenhouse glass, in cellars, poultry houses, dairy barns, hog houses, and on fences. Nor is its uses restricted to the farm, for it is applied to wood and fabrics to make them heat resistant and fire retardant, to protect concrete against the action of oils and other fluids, and to prevent rust on some kinds of steel structures. Many other uses have been found for whitewash which need not be mentioned here.

The spray outfit has displaced the brush in applying whitewash and cold-water paints, because the coating may be applied more evenly and quickly, and this fact makes a discussion of it all the more appropriate in a manual of this sort.

Success in applying whitewash depends on straining the mixture into the spray tank through a strainer of medium fine mesh, to remove coarse particles, and on diluting the mixture sufficiently to allow its ready passage through the nozzle. The spray pump is not only a labor saver, but it covers rough surfaces more thoroughly and smoothly. Some firms make special spray pumps for the application of whitewash, mortar, cement, etc., and they are equipped with brushes which revolve horizontally on the agitator, constantly cleaning the intake strainer on the pump. While these outfits are very efficient and may also be used for orchard and garden spraying, the usual types of sprayers

¹Ore. Agric. Exp. Sta., Third Crop Pest Report, 1915-20, p. 70.

²Purdue University, Extension Leaflet 49.

will apply whitewash satisfactorily if the directions mentioned in this exercise are observed.

In applying whitewash, the nozzle should be moved rapidly over the surface to be covered, otherwise too much may be applied and it will be streaked when dry. The tendency is to apply too much because the surface does not look white immediately. The whiteness comes with drying. On smooth lumber which is being whitewashed for the first time, a second, or even a third coat may be necessary.

Formula:

Stone lime	50 lbs.
Water	10 gals.
or	
Hydrated lime	50 parts
Water	60 parts

Directions:

Place the lime in a container and pour water over it. This amount of water should be sufficient to slake the lime properly and without burning, but limes differ in the amount of water required for slaking.

By placing a piece of carpet or burlap over the container, the heat will be conserved, and the slaking hastened. Be careful not to allow the lime to become dry so that it burns. Scorched lime is usually lumpy and not all in the hydrated form.

After slaking is completed the amount of water added will depend on whether the whitewash is to be applied with a brush or with a spray outfit. When applied with a brush it may be much thicker than when passed through the ordinary disk nozzle, but it may be brushed on so thickly that it soon flakes off.

THE VALUE OF SALT

The addition of $4\frac{1}{2}$ pounds of salt to the mixture greatly increases the solubility of the calcium hydroxide, and the penetration of the lime into the wood. The presence of salt will also aid in the retention of moisture and the carbonation of lime, and it makes the whitewash more durable.

A SUBSTITUTE FOR STONE LIME

Hydrated lime, though not so adhesive as stone lime, has been used with success. Good stone lime containing 90 per cent or more of calcium oxide is often difficult to obtain, and must be used at once, while hydrated lime may be obtained almost anywhere and will keep indefinitely. A few users claim greater success for hydrated lime used with glue or other adhesives.

Make up 1 quart of the whitewash formula designated by the instructor and set aside a sample in a glass cylinder for observation. Apply some with a brush to a small piece of board and allow to dry.

Notes:

Describe the physical properties of the mixture made up in laboratory, and compare with other formulas which follow this exercise, in workability of the mixtures, hiding power and cost. Part of this information will be secured by a comparison of the coating of boards.

References:

Bailey's Farm and Garden Rule Book, p. 509, 1911.

Scientific American Cyclopedia of Formulas, p. 670, 1921.

Journal of Industrial and Engineering Chemistry, Vol. 14, No. 6, pp. 503-11, 1922.

EXERCISE NO. 51

WHITEWASH FOR INTERIOR APPLICATION

Formula:

Stone lime.....	1 bu. or 62 lbs.
Rye flour.....	2½ lbs.
Rock salt.....	2½ lbs.
Water.....	20 gals.

Directions:

Slake the lime in a barrel or other container with 15 gallons of water. Keep covered to conserve heat and stir occasionally until slaked. Beat up the rye flour in $\frac{1}{2}$ gallon of cold water and then add 2 gallons of boiling water. Dissolve the salt in $2\frac{1}{2}$ gallons of hot water and mix with the rye flour paste. The flour is added to increase the adhesiveness of the whitewash. Then pour this mixture with the lime and stir thoroughly until well mixed. This should give a mixture of perfect brush consistency. If it is to be used in a sprayer add more water and strain to remove coarse particles. Make up 1 quart of this whitewash and pour some in a glass cylinder for observation. Also apply a coating to a piece of board and set aside to dry.

ADHESIVE MATERIALS

Three pounds of rice flour, 1 pound of ground glue may vary in their degree of adhesiveness, but each one will add to the durability of the whitewash. Hoof and horn glue will not dissolve readily in water, but any of the numerous grades of glue used by paperhangers and painters will answer the purpose. If any of these materials are used for whitewashing exteriors some one of the so-called preservatives should be added to prevent decomposition. Among the preservatives are alum, arsenic compounds, carbolic acid, naphthalene, salicylic acid, thymol, and zinc salts. Alum, for instance, should be added

at the rate of 1 ounce to every gallon of whitewash. The local drug store will carry some of these materials. The addition of these preparations probably hardens the organic matter in whitewash and renders it insoluble rather than merely preserving it.

GLOSSY WHITEWASH

To produce a glossy finish dissolve 1 pound of ordinary soap in a gallon of boiling water and add to every 5 gallons of whitewash. Soap does not increase the durability of the mixture.

COLOR IN WHITEWASH

Any color desired may be obtained by mixing small quantities of lampblack, brown sienna, ocher or other coloring material in the proper proportions. See Scientific American Cyclopedia of Formulas.

STORING WHITEWASH

Exclude dirt by covering the tub or container in which the whitewash was prepared, and add water enough to cover the concentrated mixture. If the water is allowed to evaporate the lime becomes useless, but when constantly covered with water it may be kept indefinitely.

Notes:

Describe the physical properties of the mixture and compare with the other samples. Also compare the coating on the board.

References:

Bailey's Farm and Garden Rule Book, p. 509, 1911.

California Cir. 204, p. 31, 1918.

Scientific American Cyclopedia of Formulas, p. 670, 1921.

Journal of Industrial and Engineering Chemistry, Vol. 14, No. 6, p. 503-11, 1922.

EXERCISE NO. 52

WHITEWASH FOR EXTERIOR APPLICATION

Formula:

Hydrated lime	50 lbs.
or	
Stone lime	38 lbs.
Sodium phosphate	3 lbs.
Casein (prepared)	5 lbs.
Water	10 gals.

Directions:

Stir water into the lime, dissolve the casein in the solution of sodium phosphate, and mix with the lime water. Casein in the form of 2 gallons of skimmed milk may be substituted for the commercial brand mentioned in the formula. This is a very durable mixture for exterior work.

If the whitewash is to be applied with a spray outfit it should be thinned down with water until it will pass through a 20-mesh sieve into the spray tank.

When whitewash is applied with a brush, it should be spread lightly over the surface, and not brushed in, like an oil paint.

GOVERNMENT WHITEWASH

This formula is so widely known and used that it must receive mention here. It has long been accepted as a standard exterior whitewash, yet in recent comparative tests it did not have the durability of simpler formulas, having even less adhesiveness than hydrated lime and water. If this formula must be used the addition of 3 pounds of sodium phosphate and 5 pounds of casein will improve it. Without these materials it is more suitable for interior than for exterior use.

Formula:

Stone lime (freshly burned)	40 lbs.
Salt	16 lbs.
Rice or rye flour	3 lbs.
Spanish whiting	$\frac{1}{2}$ lb.
Glue (ground)	1 lb.
Water	5 gals.

Directions:

Slake the lime in a tub or barrel, dissolve the salt in 2 gallons of boiling water and add to the milk of lime. Dissolve the glue in water and add to the lime mixture, stir the Spanish whiting and rice flour together, pour on water and work into a thin paste, then add to the lime and salt mixture.

Make up 1 quart of the formula designated by the instructor, pour off into a glass cylinder and apply a coating to a piece of board.

EXPERIMENTAL RESULTS WITH WHITEWASH FOR EXTERIOR APPLICATION

Dr. G. J. Fink¹ has recently completed exposure tests of one hundred and seventy-five formulas for whitewashes and aqueous lime paints. The mixtures were first applied to wood but later the best formulas were applied to stone, and the order of durability was found to be the same in both cases.

Forty different substances were added to the lime water singly and in certain combinations. These mixtures were applied to dry dressed cypress boards which were as uniform in grain, heart and sap as could be found. When the whitewash was applied its covering or hiding power was determined by the way it covered a black stripe painted across the center of the board. An accurate index of hiding power was secured by a special extension device applied to a microscope.

After allowing the whitewash 4 days to dry indoors, the boards were exposed to the southward at a 45° angle, on the roof of a building. Records of the tests included workability and characteristics of the mixtures, nature of dry film before exposure, condition of film after intervals of exposure of 10 days, 30 days, 6

¹Journal of Industrial and Engineering Chemistry, Vol. 14, No. 6, p. 503, 1922.

weeks, 2 months, and 3 months, and the index of the comparative hiding power of each mixture.

The results of these exhaustive tests may be summarized as follows, "Of the siccatives¹ used those such as casein, with which lime forms insoluble films, proved to be best, while those which are water soluble, such as glues, are not so satisfactory for exteriors. Several alkaline salts were used for accelerating the solution of casein, trisodium phosphate proving to be the most satisfactory. Among the addition agents used with lime in mixtures containing no definite siccativ, alum and table salt were effective in improving the workability and permanence of the whitewashes. Several formulas developed and tested are shown to be superior to most of those in common use." One of these exceptionally durable formulas is given at the beginning of this exercise.

WATER-PROOF PAINT

When a coating is desired for painting rough brick walls of light-houses to exclude moisture effectively, the U. S. government uses 3 parts of Rosendale cement and 1 part of fine sand, mixed with water. This may be added to whitewash, if desired. If brick color is desired, enough Venetian red is added to produce the desired color. Wet the wall with water before applying the paint.

SILICATE OF SODA

The addition of silicate of soda solution at the rate of 1 part to 10 parts of whitewash will produce a more fireproof cement.

Notes:

Describe the physical properties of the mixture and compare with other forms of whitewash. Also compare coatings on various boards.

References:

- Bailey, Farm and Garden Rule Book, p. 509, 1911.
- California Cir. 204, p. 31, 1918.
- California Cir. 227, p. 66, 1921.
- Scientific American Cyclopedia of Formulas, p. 670, 1921.

¹A siccativ is a drying agent.

EXERCISE NO. 53

PHENOLOGICAL NOTES

The object of this exercise is to become better acquainted with the blooming and leafing habits of our various tree fruits. This information is of obvious value in the timely application of sprays.

It is desirable for the student to observe when the dormant season ends, and to get accurate records, according to the outline below, for as many of the fruits as the instructor may designate. Other fruits may be substituted at the bottom of the table.

When this record is completed it is desirable to compare it with available records of previous years, and with weather records.

Fruit	Variety	Date				
		Leaf Buds Bursting	Full Leaf	Flower Buds Bursting	Full Bloom	Petals Three- fourths Fallen
Apple....						
Pear.....						
Quince...						
Peach....						
Plum....						
Sweet						
Cherry.						
Sour						
Cherry.						

1. How many working days were available this year for the first summer spray after taking out the stormy days?

2. How many working days did you have at the blossom spray during which effective spraying might be done?
3. Is there any way of estimating the amount of time when the sprayer is idle due to necessary repairs?
4. How much actual working time remains for the application of these two important sprays?

EXERCISE NO. 54

DORMANT SPRAY APPLICATION

The students will be divided into squads and each squad assigned to a spray outfit for which they will be responsible. Test the concentrated lime sulphur and then dilute the necessary amount to make 50 gallons of 5-degree Baumé spray. The barrel may be filling with water while measuring the lime sulphur, in order to save time. Test the finished spray after it has been well agitated.

Include the following notes in your report:

1. Atmospheric conditions.
2. Strength of concentrated lime sulphur.
3. Amount of concentrate to make 50 gallons of 5-degree Baumé spray.
4. Time required to fill sprayer.
5. Time required to empty sprayer.
6. Number, kind and age, of trees sprayed.
7. Average height of trees sprayed.
8. Amount of spray per tree.
9. Time of spraying per tree.
10. Cost of spraying per tree including labor and materials.

After the tank is emptied, it should be thoroughly rinsed and fresh water pumped through the pump, hose, rod and nozzle. Then disconnect the hose and rod and store away properly.

EXERCISE NO. 55

SUMMER SPRAY APPLICATION

The class will be divided into squads and each squad will be assigned to a spray outfit for which they will be responsible. Test the concentrated lime sulphur and add the amount necessary to make 50 gallons of 1-degree Baumé spray. To save time, have the barrel filling with water while measuring the lime sulphur. After the lime sulphur is diluted to 50 gallons, agitate the solution well and test with a hydrometer. Then add the lead arsenate. Also add nicotine sulphate if aphids are present. Each group will then spray the trees assigned to them.

A FIELD METHOD OF MIXING BORDEAUX

If Bordeaux mixture is used as the fungicide a different procedure will be followed. First have the barrel filling with water. Then mix up the hydrated lime with water to form a thin paste and pour into the barrel. When the barrel is almost full, and the lime has been thoroughly mixed with the water, pour in the copper sulphate solution which has been previously prepared by dissolving copper sulphate at the rate of 1 pound to 1 gallon of water. Hand pumps so constructed that the plunger rod to the pump cylinder can be disconnected, while the agitator rod remains attached, are very convenient to use with this method of mixing. The operator can thus provide vigorous agitation immediately which is highly desirable in preparing Bordeaux mixture. When this method is employed with a power sprayer the engine should be started as the tank is filling in order to provide thorough agitation.

Where water is pumped directly into the sprayer tank from cisterns, ponds or irrigation ditches mixing by this method does away with the need for a mixing platform. It is being used considerably by fruit growers in Western States and may largely replace the mixing platform method of preparing Bordeaux, because of its practical value. If desired, directions for the plat-

form method of mixing may be obtained by writing to the agricultural experiment station of your state.

All solutions poured into the sprayer should be run through a strainer to keep out coarse particles, thus preventing much trouble from clogging of nozzles.

Write a complete report of the work done and include the following information:

1. Name of spray (first, second or third summer).
2. Date of application.
3. Atmospheric conditions.
4. Materials used for making spray.
5. Amounts of each material used to make 50 gallons.
6. Pests controlled by this spray.
7. Time required to prepare 50 gallons of spray.
8. Time required to empty sprayer.
9. Average pressure maintained.
10. Number, kind and age, of trees sprayed.
11. Average height and spread of trees sprayed.
12. Amount of spray per tree.
13. Time of spraying per tree.
14. Cost of spraying per tree including labor and materials.

After the outfit is emptied, it should be properly cleaned. Rinse the tank thoroughly with fresh water. Then pump fresh water through the pump, hose, rod and nozzle. Disconnect the hose and the rod and store away properly.

EXERCISE NO. 56

STEAM STERILIZATION

In many of the greenhouse establishments the soil, especially in the ground beds, is not changed but is used over and over again, the same crops being planted for a period of years. This means an accumulation of disease and animal pests unless some means are adopted for their control. For this purpose soil sterilization with heat applied in the form of steam is the most effective method and is most generally used. Heat controls more fungous, bacterial and animal pests than any other known method. The principal pests it controls in the greenhouse are nematodes, cutworms, grubs, damping off, fusarium and lettuce drop.

Previous to sterilizing the soil, manure, if used, should be applied and the ground plowed or spaded and fully prepared for planting. The soil should be moist enough to promote good growth of plants but not so wet as to cause puddling when it is worked. It will take longer to bring a porous soil to the required temperature (140° or 212° F.), partly because air in the soil is a relatively poor conductor of heat. Furthermore, effective sterilization depends upon the presence of abundant moisture, since parasitic organisms are resistant to much higher temperatures when in a dry condition.

The time required for sterilizing the soil depends upon the pressure and volume of steam and the amount of soil. A safe rule is to continue steaming for half an hour after the soil reaches a temperature of 212° F. If the soil temperature is maintained at 140° F. for 3 hours it will probably be equally effective. After sterilization, the soil should not be worked until it has dried sufficiently and care should be taken not to reinfest the soil with pests by the introduction of new soil or by any other means.

There are a number of methods for steam sterilization. Among them are the steam pan, perforated pipe, steam rake or harrow and the tile method. The last-named type is installed as permanent equipment.

STEAM-PAN METHOD

This method is used successfully by many growers and gives good results, especially in open porous soils. It is well adapted to the sterilization of raised benches. The pans are made of galvanized iron of any convenient size and usually from 6 to 8 inches deep.

A steam connection is made in the end, in the side or in the middle of the bottom of the pan to which a hose 1 inch or more in diameter is attached. The pan is inverted and the edges forced from 2 to 4 inches in the soil. The soil is piled around the side and packed. Then the steam is turned on for a definite length of time, depending upon pressure and type of soil.

PERFORATED PIPE METHOD

This method is popular and very satisfactory but requires more labor. The outfit is made of a series of perforated pipes connected to a source of steam. These pipes are usually about $1\frac{1}{2}$ inches in diameter and may be made into 50 feet or any convenient lengths. Holes about $\frac{1}{8}$ inch in size are drilled in the pipes 1 to 3 inches apart. The pipes are placed about 18 inches apart and are buried about 6 inches deep with perforations in pipes placed downward. Five pipes usually constitute one set and they are connected at one end by a header which in turn is connected to the steam supply.

Directions:

Prepare the soil for sterilization. Imbed perforated pipes and place soil thermometers in various portions of soil area to be sterilized. Cover this soil with heavy canvas or other similar material and turn on steam.

Take several soil temperature readings until soil temperature reaches 212° F. Record length of time required to bring soil temperature to this point. Continue sterilization for 30 minutes. Then, if possible, take readings to determine how long it takes for soil temperature to fall below 212° F. If possible, determine how long it takes before soil reaches normal temperature as determined by readings taken before sterilization began. Record also the steam pressure available

STEAM RAKE METHOD

This method is also known as the steam harrow method. It is used successfully and requires less labor than the perforated pipe. It consists of a series of feed lines with T's so that there will be a hole every 8 inches, giving it the appearance of a harrow. These pegs are over $\frac{3}{8}$ -inch pipe and 6 to 8 inches long with the lower end pointed. At the lower end and on the same side of each peg is drilled a $\frac{3}{16}$ -inch hole for the escape of steam. The steam harrow is connected to the steam supply by a 1-inch hose. It is forced into the ground and covered over with canvas and heavy cloth to conserve the heat. It may be used effectively in sterilizing raised benches.

Directions:

Following a plan of procedure similar to the one outlined under directions in the discussion of perforated pipe method.

TILE METHOD

Tiles are placed permanently in the soil and are connected to the heating system. The original investment cost is greater but this type is cheaper in the end and more satisfactory for ground beds. One can safely use this system to sterilize at one operation one-twelfth of the area represented by the heating capacity of the greenhouse boilers. These tile can also be used for sub-irrigation in greenhouses having rather stiff clay sub-soils. By means of tile, steam is probably more thoroughly diffused to all parts of the soil as it will get into the corners, around the purlin posts, and under steam pipes. Consequently there is less chance for the sterilized soil to become reinfested with disease organisms and with animal pests. In the other methods the shifting of the sterilizer and other operations are likely to cause reinfestation.

Lines of tile are placed in the ground 30 inches apart and from 10 to 12 inches below the surface.

It has recently been found that tile which is split into two equal halves and then laid so that the openings come opposite the sides of the trench are even more efficient than whole tile. Care should be taken that the soil does not fill up and clog the openings on each side of the tile when the trench is refilled.

Directions:

See directions under perforated pipe method of sterilization.

Some growers determine time for soil sterilization by burying a medium-sized potato in the upper 6 inches of soil, the depth depending on the outfit used. When the potato is baked, the soil is supposed to be sterilized. If the potato is buried at the proper depth and in a part of the soil area to which the steam for sterilization purposes is radiated with greatest difficulty, this method may have practical value.

Notes:

Write a complete report of the particular methods used discussing all operations, steam pressure available, temperatures maintained and time required for sterilization.

FUMIGANTS

EXERCISE NO. 57

PARADICHLOROBENZENE

Paradichlorobenzene is a white, crystalline substance, insoluble in water with a strong etherlike odor and vaporizing completely under proper conditions. It is also known as paradichlor, parabenzene and P. D. B. The vapor is harmless, in reasonable quantities, to man and domestic animals, but poisonous to insects confined in the fumes for a sufficient length of time. The pure chemical vaporizes completely, so that if exposed to the air there is a certain amount of loss, but that remaining does not lose strength. The vapor is non-inflammable, five times heavier than air and readily permeates all types of soil. The chemical should be fine enough to pass through a 12-mesh sieve.

Paradichlorobenzene is applied in the fall after most of the borer moths have oviposited. At this time the larvæ are small and exposed, and therefore more susceptible to the vapor. Low-soil temperatures prevent proper volatilization and therefore applications should not be delayed. Do not apply when the soil is wet. The best time to apply the chemical is September 15th in the latitude of central Indiana.

The trees are prepared for treatment by first cleaning away the grass and weeds, leveling the soil and breaking up the surface crust in an area about 6 inches around the base of the tree. If borers are present above the ground level, some earth should be thrown around the tree and tamped so that the vapor will reach these borers. This is necessary because the gas is heavier than air and kills only the borers at the point of application or below it. Excessive gum and frass should be cleaned away.

Then apply the paradichlorobenzene evenly in a ring 1 to 2 inches wide about the tree. The inner edge of the ring should be about $\frac{1}{2}$ to 1 inch from the trunk. Use 1 ounce by measure of material for the average-sized tree, at which rate 1 pound will treat 18 to 20 trees. Cover the chemical with several shovelfuls

of dirt, making a cone-shaped mound and packing it with the shovel.

With average soil temperatures in the fall, the paradichlorobenzene will evaporate entirely in from 2 to 4 weeks. Cool, wet weather will retard evaporation. Therefore, under certain conditions, it is best to remove the mounds in from 2 to 3 weeks after the application.

Paradichlorobenzene can be used safely on peach trees 6 years or older, and experiments indicate that it may be used on younger trees provided proper care is exercised. Recent experiments also indicate that paradichlorobenzene may be used on other stone fruits but that it is harmful to pome fruits. It is not necessary to remove the vegetation from about the base of the trees growing in sod, but it is generally advisable.

References:

- U. S. Dept. of Agric. Bul. 707, p. 23, 1918.
- New Jersey Cir. 126, 1921.
- U. S. Farmers' Bul. 1246, p. 10, 1921.
- Purdue Ext. Leaflet 121, 1921.

EXERCISE NO. 58

CARBON DISULPHIDE

Carbon disulphide is an insecticide which may be used in many different ways for the destruction of insect pests. It is used most extensively for controlling insects infesting seeds and grains. Carbon disulphide is a clear liquid which when exposed to the air volatilizes quickly, forming a vapor which is highly inflammable and explosive when mixed with certain proportions of air. It is 2.63 times as heavy as air and has great penetrating power. The pure chemical is completely volatile, leaves no stain and will not injure the most delicate fabrics.

For reasons given above carbon disulphide should be kept away from fires of all kinds.

The gas is poisonous, producing dizziness, vomiting, congestion, coma, and finally death. It numbs the senses and increases the heart action. Persons having heart trouble should be very careful when using carbon disulphide. Under any circumstances do not inhale any more than absolutely necessary.

In order that the use of carbon disulphide be effective the vapors must be confined. This means that the building, room or container which is being fumigated must be gas-tight. The temperature during fumigation should never be below 60° F. and a temperature of 75° F. would be best. The amounts to be used may vary from 10 to 20 pounds per 1000 cubic feet, depending upon the tightness of the fumigating chamber. The fumigation should continue for 24 hours. Carbon disulphide may be poured directly on the materials to be treated or in shallow pans which are placed high in the chamber.

For fumigating small quantities of seed, a can such as a lard can will make an excellent container. Place the seed in the can and pour on about 30 c.c. or 1 fluid ounce of carbon disulphide. This is usually the amount for about 6 cu. ft. of space. Then place a couple of sheets of heavy wrapping paper over the top and tie tightly or hold the paper down with the lid.

In fumigating large seed bins the liquid should be sprinkled over the seed, or gunny sacks should be saturated and plunged into the pile of seed to the depth of a foot or two. Sometimes the liquid is poured on the seed a foot or two below the surface, by using a pipe through which the carbon disulphide is transferred. Immediately after such treatment the seed should be covered with a tarpaulin or other convenient covering material.

Write up a complete report of the work done discussing the material fumigated, description and size of fumigating chamber, amount of carbon disulphide used, methods used in fumigating, and length of time required.

Reference:

U. S. Farmers' Bul. 799, 1917.

EXERCISE NO. 59

FUMIGATION WITH TOBACCO PRODUCTS

Fumigating with tobacco preparations is an efficient means of controlling many insect pests in the greenhouse. The products which may be used are tobacco stems, concentrated liquid extracts and papers which are impregnated with the liquid extract. Burning tobacco stems is the cheapest and most common method in use but it is the least desirable because it often discolors and scents flowers, may injure tender foliage, and the smoke is not always evenly distributed through the house. It is better to use the standard volatile or free nicotine preparations as "Nico-fume" or "Nikoteen" liquid or "Nicoticide" papers. They are more convenient to use and more effective.

Fumigation should be done after sunset. If the atmosphere in the houses is moist, the smoke will settle about the plants. Therefore it is best to wet down the walks before fumigating. Do not wet the plants. All doors and ventilators should be closed tightly, shortly before starting fumigation, and the operator should leave the house without delay after fumigation has begun. The temperature of the house should not be over 60 degrees during fumigation.

TOBACCO STEMS

Plunge the stems for a moment in water and allow to drain. This will moisten the stems sufficiently to cause them to burn slowly and produce a dense, heavy smoke. Then place the stems in small compact heaps about 25 feet apart along the center walk. Beginning at the remote end, light the stems and blow out flame so the stems will smolder. Sometimes dry material as paper or straw is used to start the burning. Some growers use metal containers in which to burn the stems.

NICOTINE LIQUID

Have lowest steam pipe cold. Pour a small amount of the liquid into a tin cup and with a paint brush apply a thin coat to the lowest pipe.¹ The amount to be used for general purposes is 1 fluid ounce to 4000 cu. ft. of air space. Turn steam into pipe. Close house for about 2 hours before giving any ventilation. Special vaporizing lamps may be used, as they are very satisfactory and those burning alcohol are preferable.

NICOTINE PAPERS

Roll the papers loosely and suspend near the floor so fumes will be near the plants. Four to five papers should be used to 1000 sq. ft. of ground surface. Light lower end of paper evenly and blow out the flame so that the papers will smolder.

Write up a complete report of each method of fumigation, describing the materials used, amounts used, size of house, methods used, results secured, and cost of each method. Discuss the advantages and disadvantages of each method.

TOBACCO DUST

This is an old-fashioned form giving practically the same effects as tobacco stems. It may be purchased in bulk or in prepared form. The bulk tobacco is used at the rate of 5 pounds to a house 25 feet by 100 feet.

Put a layer of tobacco dust on a perforated pie tin, tilt it against a brick, and ignite the lower edge. To start the fumigation more readily a few drops of kerosene may be added. The cost is about the same as for other fumigants.

References:

- White, E. A., Principles of Floriculture, 1915.
- Herrick, Insects, Economic Importance, p. 19, 1915.
- U. S. Dept. of Agric. Bul. 707, p. 24, 1918.
- Journal Econ. Ent. Vol. 12, p. 349, 1919.

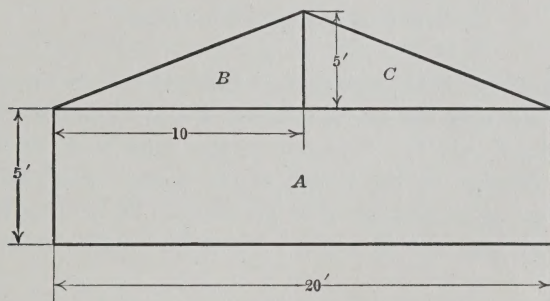
¹ Pouring the liquid on the pipe from a large oil can or a partly stoppered bottle is a quicker method.

EXERCISE NO. 60

TO DETERMINE THE CUBIC CONTENTS OF GREENHOUSES

The first step is to secure the following dimensions: width, length, height of eaves and height of ridge of the house. Then make a diagram indicating the necessary dimensions as illustrated below.

EVEN-SPAN GREENHOUSE



To secure the cubic contents, first determine the area in square feet of the rectangle A and the triangles B and C. The sum of the areas A, B and C is then multiplied by the length of the house. Let us take for example an even-span greenhouse 10 feet high, 20 feet wide, 100 feet long and the eaves 5 feet high.

$$5 \times 20 = 100 \text{ sq. ft., the area of A}$$

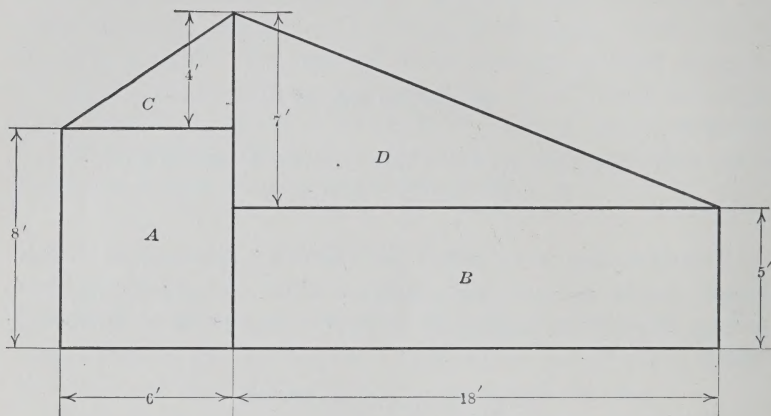
$$5 \times 10 \div 2 = 25 \text{ sq. ft., the area of B}$$

$$5 \times 10 \div 2 = 25 \text{ sq. ft., the area of C}$$

$$100 + 25 + 25 = 150 \text{ sq. ft., the area of A, B and C}$$

$$150 \times 100 = 15,000 \text{ cu. ft., the cubic contents of greenhouse.}$$

THREE-QUARTER-SPAN GREENHOUSE



Three-quarter-span Greenhouse

To secure the cubic contents of this type of greenhouse, first determine the areas of the rectangles A and B, and the areas of the triangles C and D. The sum of the areas of A, B, C and D is then multiplied by the length of the house. For example, let us consider a three-quarter-span greenhouse 24 feet wide, 12 feet high, 100 feet long with the eaves 8 feet and 5 feet above the ground.

$$8 \times 6 = 48 \text{ sq. ft., the area of A}$$

$$5 \times 18 = 90 \text{ sq. ft., the area of B}$$

$$4 \times 6 \div 2 = 12 \text{ sq. ft., the area of C}$$

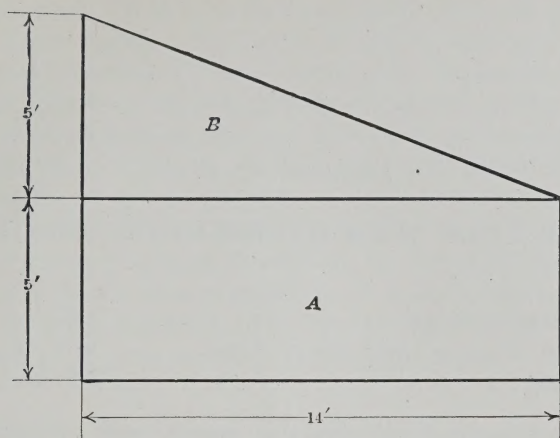
$$7 \times 18 \div 2 = 63 \text{ sq. ft., the area of D}$$

$$48 + 90 + 12 + 63 = 213 \text{ sq. ft., the area of A, B, C and D}$$

$$213 \times 100 = 21,300 \text{ cu. ft., which is the cubic contents of greenhouse.}$$

LEAN-TO GREENHOUSE

First determine the area in square feet of the rectangle A and the triangle B. Then add the areas of A and B together and multiply the sum by the length of the house. For example, consider a lean-to greenhouse 14 feet wide, 10 feet high, 100 feet long and with the eaves 5 feet above the ground.



Lean-to Greenhouse.

$$5 \times 14 = 70 \text{ sq. ft., the area of A}$$

$$5 \times 14 \div 2 = 35 \text{ sq. ft., the area of B}$$

$$70 + 35 = 105 \text{ sq. ft., the area of A and B}$$

$$105 \times 100 = 10,500 \text{ cu. ft., which is the cubic contents of greenhouse.}$$

Reference:

Farmers' Bulletin No. 880, p. 5, 1917.

EXERCISE NO. 61

FUMIGATION WITH HYDROCYANIC-ACID GAS

Formula:

Sodium cyanide ¹	1 oz.
Com. sulphuric acid (sp. gr. 1.84).....	1½ fl. oz.
Water.....	2 fl. oz.

For greenhouse fumigation this amount will fumigate from 1000 to 6000 cu. ft. of space, depending on the tenderness of the plant foliage and upon the tightness of the house.

Directions:

The gas is generated in half-gallon earthenware jars. Calculate the cubical contents of the house. Measure the amounts of each material needed. The cyanide should be weighed for each generator and put in paper bags. Place a bag near each generator. Then place the amount of water necessary in each generator and add the correct amount of sulphuric acid. Always pour acid into water, and never water into acid. When everything is ready, begin at the generator farthest from the door, and gently drop the bag of sodium cyanide in the diluted acid. Leave the house immediately. If there is more than one row of generators in a house, have an operator for each row. Post danger signs, indicating hydrocyanic-acid gas fumigation.

Hydrocyanic-acid gas is one of the cheapest and most effective means of controlling insects in the greenhouse, including such difficultly controlled pests as white fly. The gas, as well as the ingredients themselves, are deadly poisons and must be handled with great care.

¹Sodium cyanide is readily obtained, but if preferred, potassium cyanide may be used according to the following formula:

Potassium cyanide (95 to 100%).....	1 oz.
Commercial sulphuric acid.....	1 oz.
Water.....	2 oz.

Fumigation should be carried on at night and not earlier than 1 hour after sunset. The house should be tight and arrangements made so that the ventilators may be opened from the outside. The best temperature for fumigation is the optimum temperature for growing the crop which is to be fumigated. It is not desirable to fumigate on extremely cold nights or on hot, humid nights or on windy nights.

Fumigations of short duration, usually about 2 hours, with stronger dosages, 1 ounce to 2000 cu. ft., are preferable and will give better results than fumigations of long duration with comparatively weaker dosages. The last statement applies especially to treatment of grain in bins, elevators and mills.

FUMIGATION OF NURSERY STOCK

Hydrocyanic-acid gas is also used by nurserymen for controlling scale insects and similar pests found on nursery stock. For fumigating nursery stock a gas-tight chamber or box is used. The above formula is used for each 100 cu. ft. of space. The nursery stock should not be packed closely in the chamber or box as this will prevent proper diffusion of the gas. For convenience in handling, plants may be tied in small bundles and each layer packed crosswise or separated with slats. The stock should be in the dormant condition and should not be wet as it is likely to be injured when in this condition. Fumigation is carried on for 40 minutes.

FUMIGATING CITRUS TREES

In California this gas is used for fumigating citrus trees to control scale and other insect pests. The trees are covered with reasonably gas-tight canvas tents to confine the gas about the tree. The gas is generated in earthenware pots or in special machines consisting of a generating drum and two tanks, one for sodium cyanide solution and the other for sulphuric acid. This is mounted on wheels and is easily transported. The concentrated or liquid hydrocyanic-acid gas stored in steel tanks is also used.

SPECIAL EQUIPMENT

The heat generated by the combination of sulphuric acid and water sometimes cracks earthenware jars. In such instances enameled ware of good grade may be substituted. To avoid loss of material and damage to equipment, especially when fumigating mills, wooden oil barrels are often times used. Ordinary wooden barrels not soaked with oil are not satisfactory. The film of oil in oil barrels protects the wood against the corrosive action of the acid.

It is also desirable for the operator handling sulphuric acid to dip his hands in oil to prevent acid burns.

Recent evidence indicates that hydrocyanic-acid gas generated from one or two large containers will readily diffuse throughout a large house. On a windy day such diffusion to all parts of the house is apparently not so complete. But under ideal weather conditions generators of sufficient capacity, when placed on the first floor have been known to bring about thorough fumigation of the second and even the third floors of a building. This method is much less expensive and so much more convenient that it deserves further investigation to determine its full possibilities.

Notes:

Write up a complete report of the work done including the cubical contents of the house or chamber fumigated, amounts of material used, methods employed, plants treated, effect on plants, temperature inside and outside, time for fumigation and results secured.

References:

- Farm. Bul. 880.
- Farm. Bul. 923.
- Cal. Bul. 308.

SPRAYING EQUIPMENT

CLASSIFICATION OF SPRAYING EQUIPMENT

SPRAY OUTFITS

I. Hand outfits:

1. Atomizers.
2. Bucket pumps.
3. Compressed-air sprayers.
4. Knapsack sprayers.
5. Barrel sprayers.
6. Tank pumps.

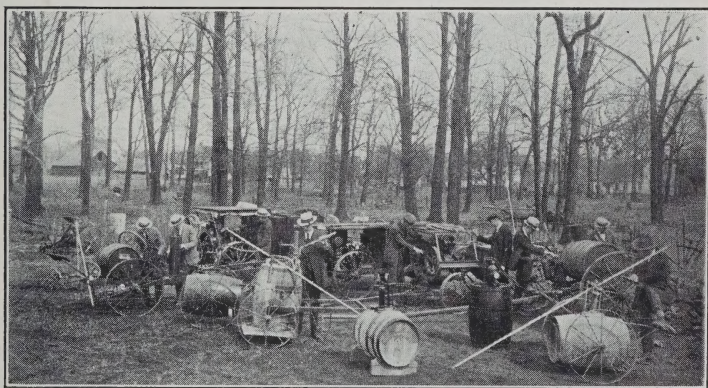


FIG. 6.—Students Making a Study of Spraying Outfits.

II. Power outfits:

1. Traction sprayers.
2. Compressed-air sprayers.
3. Gasoline-power sprayers.

SPRAYING ACCESSORIES

1. Nozzles:

- (a) Disc type (angle or straight.)
- (b) Bordeaux type
- (c) Vermorel type.

2. Nozzle Y's (angle or straight).
3. Spray rods.
4. Spray guns.
5. Shut-offs.
6. Spray hose.
7. Hose couplings.
8. Hose clamps.
9. Special equipment.

DUSTING OUTFITS

1. Hand dusters:
 - (a) Shaker type.
 - (b) Bellows type.
 - (c) Plunger and cylinder type.
 - (d) Fan blower type.
2. Power Dusters:
 - (a) Traction.
 - (b) Gasoline power.

EXERCISE NO. 62

STUDY OF SMALL HAND SPRAY OUTFITS

ATOMIZERS

Study carefully and note the principles of operation. Remove the plunger and note the kind of materials used for making the plunger. Make a drawing of the atomizer showing and labeling all parts. Supplement the drawing with a brief description.

COMPRESSED AIR SPRAYERS

Remove the pump and note the construction of the spray outfit and the materials used in making it. Also remove the plunger and note its construction. Study carefully the method of operation. Make a drawing of the complete outfit showing and labeling all parts. Include a brief description noting the above points.

BUCKET PUMPS

Remove the plunger and the part containing the valves. Note the principles of operation, construction, and materials used in making the pump. Note the type of valves and valve seats, and the size of air chamber if present. Make a drawing showing and labeling all parts. Also show the course of the liquid through the pump. Include a brief description to supplement the drawings.

KNAPSACK SPRAYERS

Remove the pump from the tank and study carefully. Remove the plunger and also the part containing the valves. Note the principle of operation. Make a drawing showing a complete longitudinal section through the pump and label all parts. Indicate the course of the liquid through the pump. In your notes, include the materials used for the various parts of the pump,

the type of valves and valve seats, the type of agitation, dimensions of air chamber, dimensions of cylinder, length of stroke and the size of intake.

Note:

After completing the study of each spray outfit replace all parts properly and leave it in perfect working order.

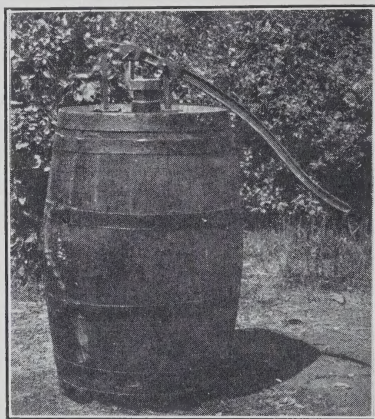


FIG. 7.—Barrel Pump Mounted on End.



FIG. 8.—Barrel Pump Mounted on Side. Not so Easily Tipped Over.

EXERCISE NO. 63

STUDY OF BARREL SPRAY OUTFITS

Remove the pump from the barrel. Then remove the plunger and the part containing the valves. Note the location and type of valves, the plunger, type of packing, and materials used in constructing the various parts. Study carefully the principles of operation.

Make a careful drawing of a longitudinal section of the pump showing and labeling all parts. Also indicate the course of the liquid through the pump. Include in your notes the following information:

1. Name of pump.
2. Manufacturer's name.
3. Where made.
4. Kind of valves.
5. Kind of valve seats.
6. Accessibility of valves.
7. Material used in constructing cylinder.
8. Diameter of cylinder.
9. Length of stroke.
10. Type of packing.
11. Dimensions of air chamber.
12. Size of intake.
13. Type of agitator.
14. Length of pump handle and amount of leverage.
15. Ease of removing pump from barrel.
16. Firmness of attachment to barrel.
17. Method of mounting on barrel.

After completing the study of the pump, replace all parts properly and leave the outfit in perfect working order.

EXERCISE NO. 64

TANK PUMPS

Remove the plunger or plungers and the valves. Note the location and type of valves, the construction of the plunger, kind of packing and its location, and the materials used in constructing all parts of the pump. Study carefully the principles of operation.

In your notes make a careful drawing of a longitudinal section of the pump showing and labeling all parts. Indicate the course of the liquid through the pump. Also write up a discussion on the principles of operation. Include in your notes the following information:

1. Name of pump.
2. Manufacturer's name.
3. Where made.
4. Type of tank pump.
5. Kind of valves.
6. Kind of valve seats.
7. Accessibility of valves.
8. Number and position of cylinders.
9. Materials used in constructing cylinder.
10. Diameter of cylinder.
11. Materials used in constructing plunger.
12. Length of stroke.
13. Type of packing and ease of renewing.
14. Dimensions of air chamber.
15. Size of intake.
16. Type of agitator.
17. Length of pump handle and amount of leverage.
18. General remarks.

After completing the study of the pump, replace all parts properly and leave the outfit in perfect working order.

EXERCISE NO. 65

TRACTION SPRAYERS

Make a careful study of the traction sprayers assigned. Pull the sprayer forward and note how it operates. Remove the plungers and valves and note the construction of the pump.

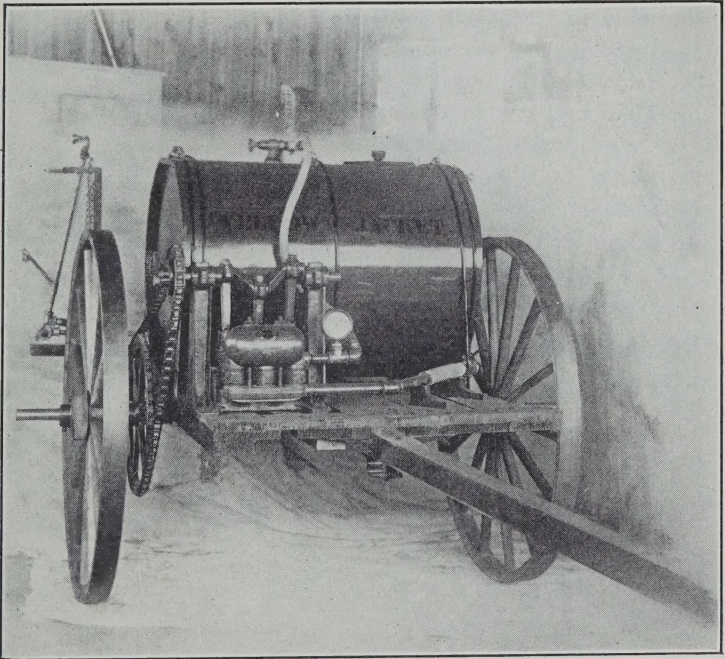


FIG. 9.—Triplex Pump Traction Sprayer. Note how the Boom is Folded up and Method of Transmitting Power from the Axle to the Pump.

Write up a complete report on each traction sprayer, describing the principles of operation and general construction of the outfit. Include the following data:

1. Name of sprayer.
2. Manufacturer.
3. Where made.
4. Description of truck.
5. Method of transmitting power to pump.
6. Device for disengaging pump.
7. Method of driving plungers.
8. Plunger cylinders: number, diameter, arrangement and materials.
9. Length of stroke.
10. Type and accessibility of packing.
11. Type and accessibility of valves.
12. Location and construction of relief valve.
13. Means for regulating pressure.
14. Location and size of air chamber.
15. Location and number of drain cocks or plugs.
16. Means for transporting spray from tank to pump.
17. Capacity and shape of tank.
18. Agitator: type and method of driving.
19. Method of lubrication.
20. Spray boom: number of nozzles, arrangement and means for adapting to various crops.
21. General remarks.

After completing the study of the sprayer, assemble the pump properly and leave the outfit in working order.

EXERCISE NO. 66

STUDY OF POWER PUMP

Take the pump completely apart, noting carefully the proper location for each part. Note carefully how each part of the pump functions and the material that it is made of. Study the principles of operation, noting how the various parts work together.

Make the following drawings:

1. Valve and valve seat in detail.
2. Plunger. Draw each part separately and show how parts go together to make the plunger. Label all parts.
3. Relief valve or pressure regulator. Draw complete in detail showing method of operation. Label all parts. Explain how it may be adjusted to change pressure.
4. Section through pump showing course of liquid through one pump with its pair of valves, through the relief valve and air chamber to the outlet. Indicate all valves properly. Include a brief description explaining how each part operates.

Assemble the pump properly and leave in perfect working order.

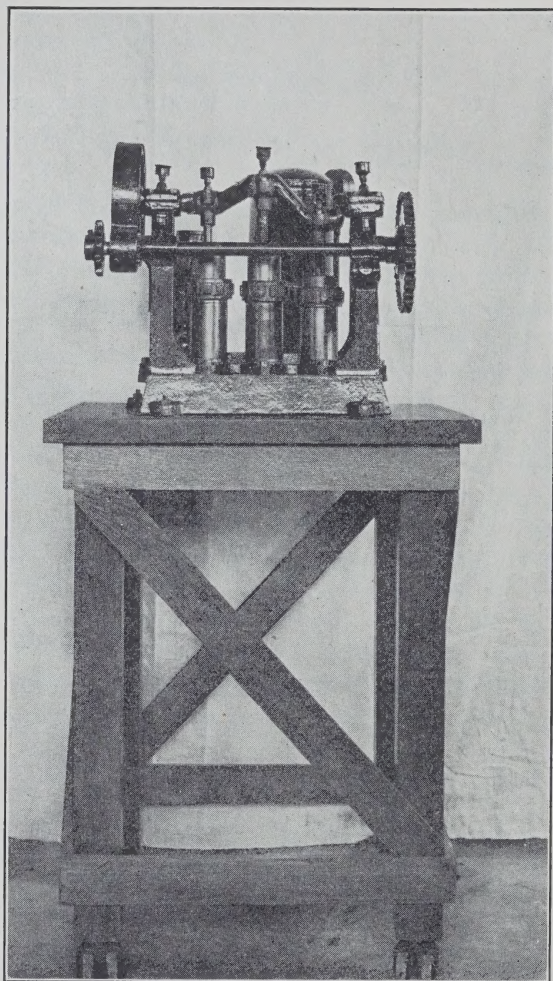


FIG. 10.—Power Pump Mounted on Movable Table for Study in Laboratory.
Can be Easily Taken Down and Re-assembled

EXERCISE NO. 67

STUDY OF GASOLINE POWER SPRAYER

Study carefully and thoroughly the power sprayer outfit assigned. Start the engine and study the operation of the pump

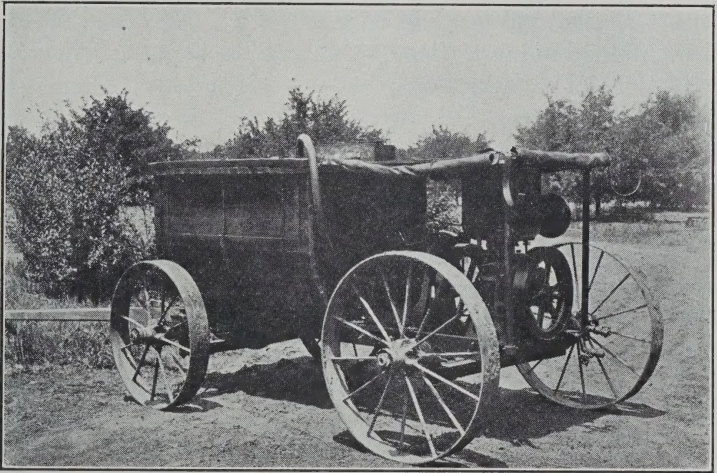


FIG. 11.—Triplex Power Sprayer. A Good Type of Orchard Sprayer. Note the Under-slung Axles Making the Outfit Low and the Large All-steel Wheels with Wide Rims. Spray Material is Carried to Pump by a Suction Hose.

while running. Write a report including the following information:

1. Name of sprayer.
2. Manufacturer.
3. Where made.
4. Description of truck.
5. Horsepower of engine.
6. Method of transmitting power to pump.

7. Plunger cylinders: number, diameter, arrangement and materials.
8. Length of stroke.
9. Method of driving plunger (crankshaft or eccentric).
10. Type of packing.
11. Accessibility of valves.
12. Location of relief valve.
13. Location and size of air chamber.
14. Location and number of drain cocks.
15. Apparatus for filling tank.
16. Method of transporting liquid from tank to pump.
17. Type of agitator and method of driving.
18. Capacity and shape of tank.
19. Method of lubrication.
20. General remarks.

EXERCISE NO. 68

STUDY OF MISCELLANEOUS ACCESSORIES

SHUT-OFFS

Study the different types of shut-offs assigned in laboratory and make a sectional drawing of each. Show all parts of the shut-off and label. Include with each drawing a description noting the materials used in its manufacture. Also make note of construction, the ease of operation and size of the waterway. Which type do you think represents the poorest principles in construction? Which type would you buy?

HOSE COUPLINGS

Make drawings of the various makes of couplings to be found in laboratory and name them. Supplement the drawings with a description noting the construction, materials used, durability, and size of waterway. Make comparisons of the various couplings noting the advantages and disadvantages of each.

HOSE CLAMPS

Make drawings of the various kinds of hose clamps available in laboratory. With every drawing include a brief description noting the advantages and disadvantages of each kind of clamp.

EXERCISE NO. 69

STUDY OF SPRAY NOZZLES AND GUNS

SPRAY NOZZLES

For purposes of study nozzles may be classified into four important groups, namely, Vermorel, Bordeaux, disk and solid stream.

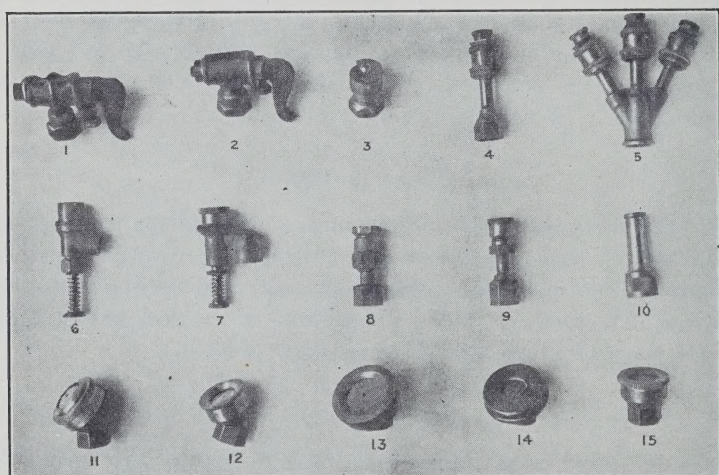


FIG. 12.—Nozzles.

- | | | |
|---------------------|------------------------|-----------------------------------|
| 1, 2—Bordeaux | 6—Vermorel | 11, 12, 13, 14—Angle Disk Nozzles |
| 3—Modified Bordeaux | 7—Demorel | 15—Straight Disk Nozzle |
| 4—Single Caswell | 8, 9—Modified Vermorel | |
| 5—Triple Caswell | 10—Solid Stream | |

Some nozzles are modifications of the original Bordeaux or the true Vermorel. The disk type includes the basic principles of the original Vermorel in improved form. The solid stream designs have been evolved from the pattern of a garden hose nozzle.

Study the nozzles available in laboratory and classify each

according to the classification outlined above. The discussion of nozzles found elsewhere in the manual may serve as a guide.

Take each nozzle apart and describe its construction and the kind of materials from which it is made. Make a sectional drawing of each nozzle showing and labeling all parts. Supplement the drawing with a description of the nozzle including how it operates, the size of the orifice in the disk and size of the eddy chamber, if present. Assemble each nozzle after completing the work.

Reference:

West Virginia Bul. 169.

SPRAY GUNS

Study carefully the various kinds of spray guns available in laboratory. Take them apart and describe their construction, the materials used in their manufacture, and how the gun operates. Make a careful sectional drawing of each gun assigned. Show and label all parts. Supplement the drawing with a description of the gun stating as well as you can what type of control regulates the flow of liquid through the nozzle. Note also the diameter of the orifice in the disk, and make practical comparisons of the gun you are considering, with others which have already been studied.

Reference:

Oregon Station Bul. 171.

This reference deals with the operation of the gun and its efficiency as compared with dusting and with the rod and disk nozzle.

EXERCISE NO. 70

CAPACITY OF SPRAYERS AND NOZZLES

The class will be divided into squads and each squad will do all the work individually.

The first part of the work will be to test the capacity of barrel sprayers and power sprayers. Use the same rod and nozzle for testing each outfit in order to secure comparative results. Attach hose and rod to pump and develop a uniform pressure. Then direct the spray into a bucket for 1 minute. Measure the amount of liquid and note the pressure developed. Develop the same pressure for each of the barrel pumps. Follow the same procedure for testing the power sprayers. Write up the data secured in tabular form including the name of the spray outfit, the pressure developed, the ease with which the pressure may be maintained, the capacity in gallons per minute and a general statement of the type of nozzle used for testing.

The second part of the exercise will be to test various types of nozzles. Select a barrel pump and test all nozzles on the same pump and at the same pressure for the flow of liquid per minute. Also direct the spray from each nozzle against a muslin sheet and note the evenness of distribution, whether good, fair or poor. Follow the same procedure using a power sprayer. Tabulate this information including the name of the nozzle, size of disk opening, capacities for each pressure developed, and evenness of distribution.

Also write up a general summary of the results secured.

EXERCISE NO. 71

STUDY OF SPRAY GUNS

The purpose of this exercise is to test the capacity of various kinds of spray guns and the quality of spray for each at various pressures.

The class will first be divided into squads and each squad

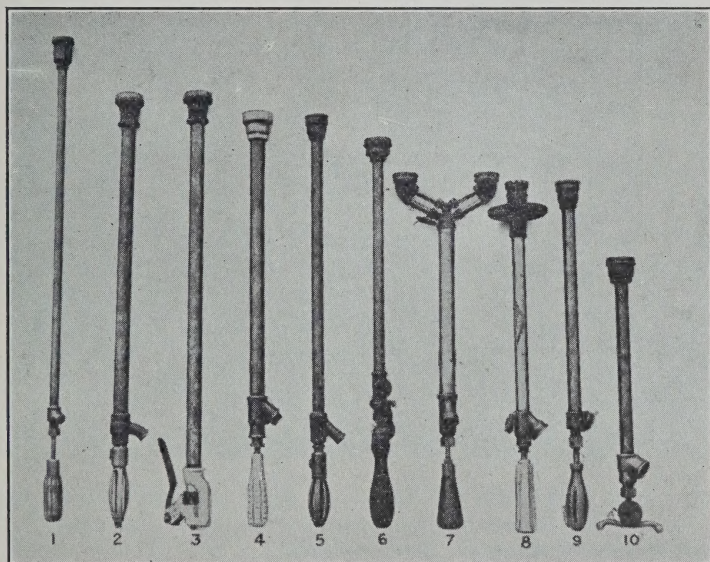


FIG. 13.—Ten Different Designs of a Spray Gun.

1—Friend Universal
4—Hardie
7—Boyce

2—Wardle (New Design)
5—Bean
8—Comet

3—Wardlo
6—Myers
10—Friend

assigned to a power sprayer. Each squad will test all spray guns assigned on their power sprayer.

Start the engine and adjust the relief valve until a uniform pressure of 200 pounds is developed. Attach each spray gun in

turn to the hose. Use disks with orifices of the same diameter in each gun tested. Note the maximum and minimum length of stream, the quality of distribution by directing against a muslin sheet and the flow of liquid per minute with gun open full. Follow the same procedure using the same guns after adjusting the sprayer to develop a pressure of 250 pounds and also a pressure of 300 pounds.

Arrange this information in tabular form according to the outline below.

Name of Spray Gun	Diameter of Opening	Pressure Developed	Length of Stream		Capacity Gallons per Minute	Quality of Distri- bution
			Maxi- mum	Mini- mum		

Write up a general summary of the results secured.

EXERCISE NO. 72

CONSTRUCTION AND OPERATION OF SPRAYOGRAPH¹

The principle of design of the sprayograph is taken from the focal plane shutters used on cameras of the graflex type. The

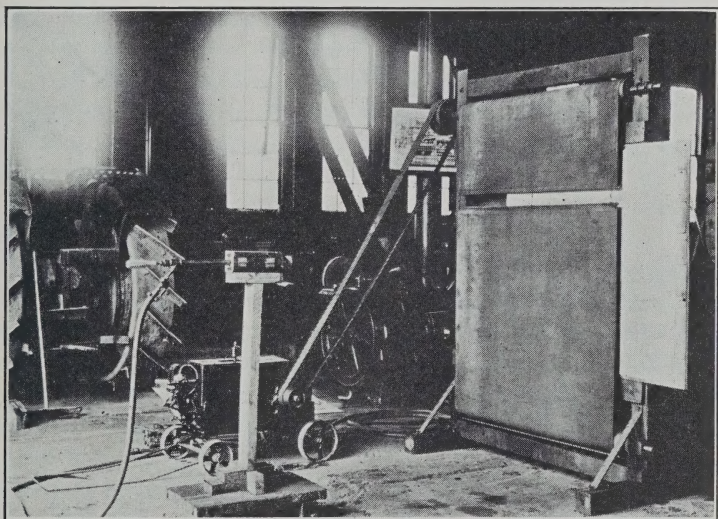
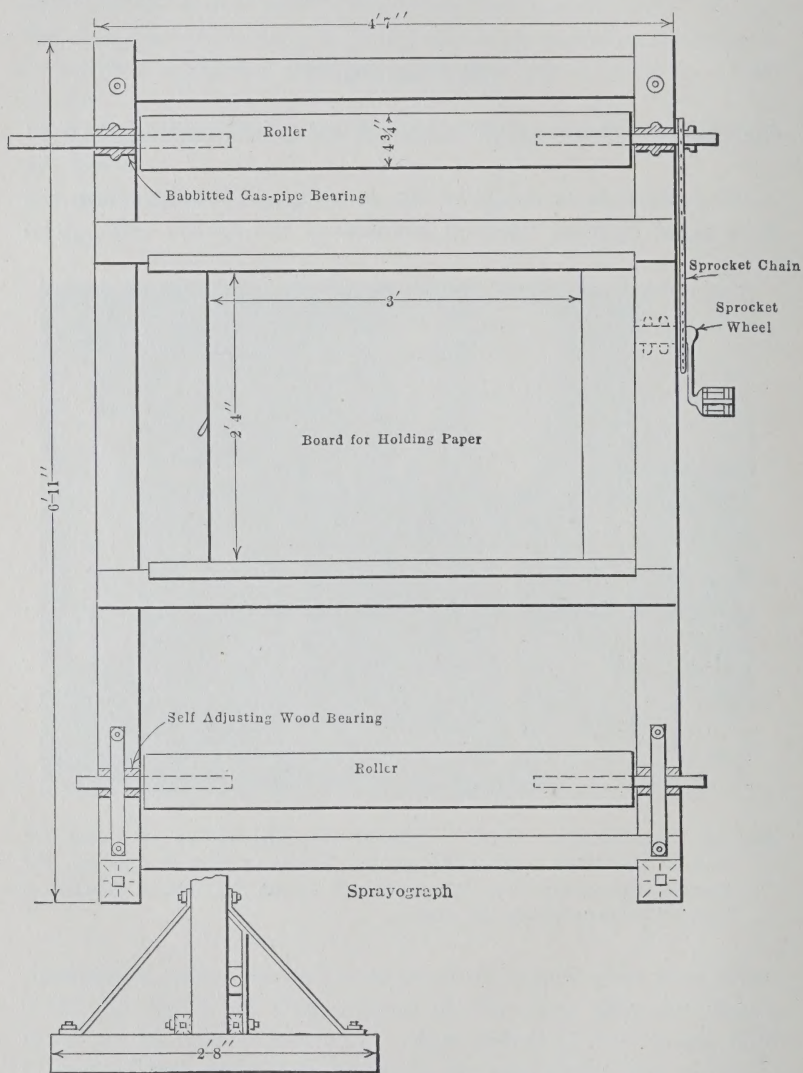


FIG. 14.—Sprayograph. Used to Record the Distribution of Spray for Nozzles and Guns. After Placing the Nozzle or Gun in Position, the Shutter is Revolved at a Definite Speed. Then the Colored Solution is Sprayed on for a Single Revolution.

frame may vary widely in dimensions but one which is compact, simple, portable and easy to operate may be 6 feet 11 inches high and 4 feet 11 inches wide. Two rollers each $4\frac{3}{4}$ inches in diameter and 4 feet long are mounted at the top and bottom of

¹ Thesis Work by G. H. Castrup and W. Williams, 1916, Department of Horticulture, Purdue University.

the frame. The top crosspiece and two uprights are united by a half and half joint and are made of 4 by 4 inch lumber, the uprights being fastened to the basal support by a mortise and tenon joint.



End View Showing Basal Support
and Movable Bearing

FIG. 15.—A Detailed Drawing Showing Construction of Sprayograph.

Steel shafts $\frac{15}{16}$ of an inch in diameter extend into the rollers about 8 inches. The bearings supporting the top roller are sections of gas pipe babbitted to fit the shafts, and containing holes for oiling.

Stretched over the rollers is a waterproof curtain made of oiled duck, and cut sufficiently short so that the ends will not meet, but will leave a horizontal opening the width of the curtain and from $1\frac{1}{2}$ to $3\frac{1}{2}$ inches in width vertically.

The lower roller is free, the shafts being supported by sliding maple bearings. By this means the weight of the lower roller is allowed to rest on the canvas, keeping it taut.

The sprayograph may be operated by gears, chain and crank as shown in the picture, or by means of a pulley rigged to the lower roller and operated by an engine or electric motor.

In the open space between the front and rear flaps of the canvas stretched over the rollers, provision is made to insert a board 3 feet by 2 feet 4 inches. A piece of paper of this size is tacked to the board, the paper serving the same purpose for the sprayograph that a negative or a film serves for a camera.

Operating the Outfit:

A stand similar to the one shown in the accompanying picture should be provided and so constructed that it will hold all nozzles firmly in place and at the same angle with the canvas. Then the curtain should be revolved at various speeds to determine the best speed to use for the nozzles and pressures involved. Nozzles of small capacity may be stationed about 2 feet from the canvas for testing purposes. Professor Crane of West Virginia University found that for small nozzles, when the slot was $3\frac{1}{2}$ inches wide, an exposure of .02365 second or sixty revolutions of the curtain per minute gave the best results. Bordeaux types and spray guns record well from a 5-foot station.

As the canvas is revolved (in either direction), the slot in it travels across the paper and transfers to it an exact reproduction of the spray distribution of the nozzle under test. Whether the fineness of the spray is actually photographed or not depends on the grade of paper. It should be a grade less absorbent than newspaper, for the latter when it dries, reveals a distorted record, similar to the ink marks on a blotter.

The water used for nozzle tests is tinted a bright color, Orange Y being used successfully at West Virginia and Purdue Universities.

DUSTING EQUIPMENT

EXERCISE NO. 73

STUDY OF HAND DUSTERS

SHAKER TYPE

Study carefully and note the materials used in construction and the method of operation. Make a sectional drawing and label all parts.



FIG. 16.—Hand Blower Duster in Operation.

BELLOWS TYPE

Note the materials used in construction and method of operation. Make a sectional drawing and label all parts.

PLUNGER AND CYLINDER TYPE

Remove the plunger and the hopper. Note the principle of operation and the construction of the outfit. Make a sectional drawing and label all parts.

FAN BLOWER TYPE

Study carefully the construction of the outfit and method of operation. Make a sectional drawing and label all parts.

EXERCISE NO. 74

TRACTION DUSTERS

Make a careful study of the traction duster assigned in laboratory. Move the outfit forward and note its method of operation. Remove any parts necessary in order to study the various parts and principles of operation in detail.

In your notes make a sectional drawing through the hopper and blower showing and labeling all parts. Write up a complete discussion of the outfit including the following information:

1. Name of duster.
2. Manufacturer.
3. Where made.
4. Description of truck.
5. Method of transmitting power to blower.
6. Means for disengaging blower.
7. Size of fan.
8. Kind of bearings and method of housing.
9. Speed of fan.
10. Shape and capacity of hopper.
11. Method of feeding dust to air chamber.
12. Means of regulating the amount of dust.
13. Size of pipe for carrying dust to nozzles.
14. Number and arrangement of nozzles.
15. Means for adjusting nozzles.
16. Materials used in constructing the various parts.
17. Method of lubrication.
18. General remarks.



FIG. 17.—Students Learning to Use Various Types of Hand Sprayers and Dusters.

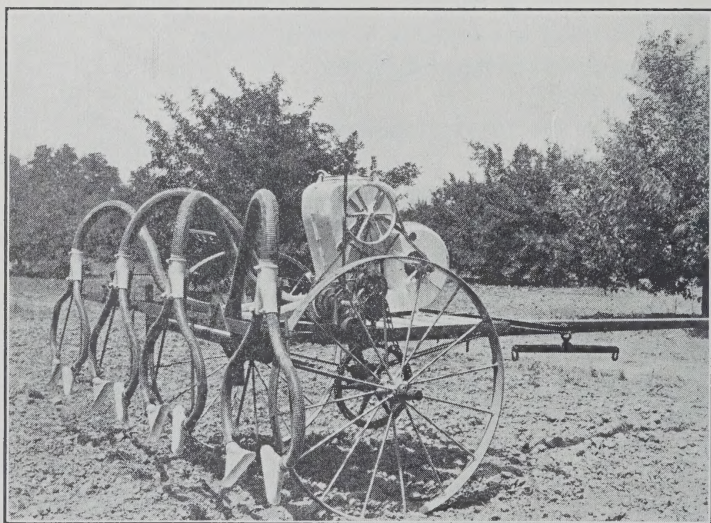


FIG. 18.—Traction Duster. A Good Type for Dusting Truck Crops. Note the Large Flexible Metal Tubes which Carry the Dust to the Nozzles and the Arrangement of the Nozzles. Also Note the Method of Transmitting Power from the Axle to the Blower.

EXERCISE NO. 75

STUDY OF POWER DUSTER

Study carefully the power duster assigned in laboratory. Start the engine and study the operation of the duster while running. Remove any parts necessary in order to study in detail the various parts and principles of operation.

Make a sectional drawing through hopper and blower and label all parts. Include in your report the following information:

1. Name of duster.
2. Manufacturer.
3. Where made.
4. Description of truck.
5. Horsepower of engine.
6. Method of transmitting power to blower.
7. Method of disengaging engine.
8. Size of fan.
9. Type of bearings and method of housing.
10. Speed of fan.
11. Shape and capacity of hopper.
12. Method of feeding material.
13. Ease of adjusting feed.
14. Size of discharge.
15. Method of lubrication.
16. General remarks.

COST PROBLEMS

EXERCISE NO. 76

COST OF GREENHOUSE FUMIGATION

The object of this exercise is to determine the cost of controlling insects in a greenhouse.

The greenhouse is 40 feet wide by 100 feet long, 6 feet to eaves and 18 feet to the ridge. It is necessary to find the cubic content of the greenhouse before the amount of fumigating material can be determined.

Greenhouse fumigation is sometimes a matter of experimentation until a grower knows the individual requirements of each house. This is due to varying degrees of air tightness.

For most greenhouse crops the commonest insect pests are aphids and white fly, although there are a number of others. These are controlled by fumigation with some free nicotine preparation (40 per cent nicotine) usually at the rate of 1 ounce to 1000 to 4000 cu. ft. of greenhouse space.

For surer effects hydrocyanic-acid gas is used, although its extremely poisonous character prevents its use on a more extensive scale. The following materials are used in fumigating with hydrocyanic-acid gas:

1 oz. sodium cyanide	}	per 1000 to 6000 cu. ft.
1½ oz. sulphuric acid		
2 oz. water		

Using the above formula and the prices furnished by the instructor:

Cyanidelb.; sulphuric acidlb.; nicotine sulphate
.gal. figure the cost of one fumigation:

1. At the weakest strength of nicotine sulphate.
2. At the strongest rate.
3. At the weakest strength of hydrocyanic-acid gas.
4. At the strongest strength of hydrocyanic-acid gas.

What would it cost the grower a year to fumigate, using each of the above materials? The strength and the number of fumigations per season will be determined by the instructor.

References:

E. A. White, Principles of Floriculture.

L. H. Bailey, Standard Cyclopedia of Horticulture.

EXERCISE NO. 77

THE RETURNS FROM SPRAYING APPLES

Given a 10-acre block of mature apple trees, to determine the probable net gain from the proper application of sprays for your locality (use local, state or Federal spray schedule).

The trees are planted 40 feet by 40 feet, the soil management has been clean culture with cover crops.

Equipment: A power sprayer with 200-gallon tank capable of handling one gun and one rod or two rods, each rod having two nozzles with small disk orifices.

Crew: Two horses, two men, one man working from a tower and driving the team.

Water supply: Tank located at southwest corner of the block. On the average it takes 30 minutes to fill tank and resume spraying.

Spray Materials	Cost
Lime sulphur	———per bbl.
Arsenate of lead	———per 100 lbs.
Copper sulphate	———per 100 lbs.
Stone lime or hydrated lime	———per 100 lbs.
Nicotine sulphate	———per gallon
Labor	
Cost of team and man	———per 10 hr. day
Cost of man labor	———per 10 hr. day
Cost of spray outfit	———
Depreciation on equipment at 20% per year	———

Check Plot:

Five trees in this orchard which were not sprayed showed 20 per cent clean fruit; 30 per cent second grade; 25 per cent culls and 25 per cent unsalable.

Sprayed Block:

These trees showed 85 per cent clean fruit; 10 per cent second grade, and 5 per cent culls.

Determine from available literature what the average yield of fruit should be from sprayed trees which are mature. Also the yield from unsprayed trees.

The apples may be sold as follows:

1st grade	———per bushel
2nd grade	———per bushel
Culls	———per 100 lbs.

References:

- Folger and Thomson, Commercial Apple Industry, Macmillan, p. 229.
 LeRoy Childs, Spray Gun versus Rod and Dust in Apple Orchard Pest Control, Oregon Sta. Bul. 171, 1920.
 Lewis, C. I., and Vickers, H. A., Economics of Apple Orchard, Oregon Sta. Bul. 132.
 Hedrick, U. P., Ten Years' Profits from an Apple Orchard, Geneva Bul. 376, 1914.

Notes:

If preferred, this problem may be applied to a peach or plum orchard, and dusting may be substituted for spraying.

Prices vary from year to year and in different regions.

EXERCISE NO. 78

THE COST OF SPRAYING

The object of this exercise is to apply the knowledge gained from a study of spray materials, machinery and schedules to the business management of a commercial orchard.

So far as the problem allows, its application to local conditions and to an orchard with which you are familiar, is desirable and will make it more interesting.

The orchard of 30 acres is planted to apples and peaches. All plantings are on a moderate slope, and the soil is a clay loam. Block A is 20 years old, 20 acres in extent, planted to the square system 35 feet by 35 feet and contains the following varieties:

- 5 A Yellow Transparent.
- 5 A Duchess.
- 5 A Jonathan.
- 5 A Ben Davis.

This block was cultivated for the first 8 years, then sod mulch was adopted, the grass being cut and allowed to remain where it fell.

Block B contains 5 acres of Baldwin, 7 years old. This block has received cultivation and cover crop treatment and is planted on the square system 40 feet by 40 feet. Elberta peach trees of the same age have been planted between the apple trees on the double filler system (fillers in the apple rows and a solid row of fillers between rows of apples).

Block C contains 5 acres of Delicious, 5 years old, planted to the square system 40 feet by 40 feet. Inter crops have been used as a source of early financial return.

In order to spray this orchard properly, the following information will be necessary:

1. Knowledge of spray schedules as applied to local conditions.
2. Differences in kind or strength of spray applied due to variety or kind of fruit.
3. Number of trees per acre.

4. Amount of spray mixture required per tree (the amount will vary with the nozzle used).
5. Sod mulch, or clean cultivation: Are insect and disease pests more easily controlled under one system of management than the other?
6. Water Supply:
 - a. Pond or irrigation ditch.
 - b. Tank wagon.
 - c. Overhead tank supply.

Select the water supply adapted to your problem and figure out how long it will take to fill a 200-gallon spray-tank.

Submit a statement giving the total amount of each spray material needed for the season in each block. In Block B separate the items for peaches from the ones for apples.

If possible, obtain the best market prices for these spray materials and figure out an accurate total for the 30 acres. If definite quotations cannot readily be secured make out an estimated total.

References:

- Folger and Thomson, Commercial Apple Industry, Macmillan, 1921, Chap. 19. Also p. 229, Table 11.
- Hesler and Whetzel, Macmillan, 1917, Manual of Fruit Diseases, Chap. 2.
- Sear's Productive Orchardng, Lippincott, 1917, pp. 210-11.
- Eustace, H. J., and Barden, F. M., The Financial History of a Twelve-year-Old Peach Orchard, Michigan Special Bul. 94, 1919.
- Thomson, S. H., and Miller, G. H., Cost of Production of Apples in the Payette Valley, Idaho, U. S. Dept. of Agric. Bul. 636, 1918.
- Mowrey, H. H., Machinery Cost of Farm Operations in Western New York, U. S. D. A. Bul. 338, 1916.
- Woodbury, C. G., Richards, M. W., Reed, H. J., The Indiana Farm Orchard, Operating Costs and Methods, Purdue Station Bul. 194, 1916.
- Lewis, C. I., and Vickers, H. A., Economics of Apple Orchardng, Oregon Station Bul. 132.
- Hedrick, U. P., Ten Years' Profits from an Apple Orchard, Geneva Bul. 376, 1914.
- Ballard, W. R., Apple Orchard Experiments, Maryland Station Bul. 178, 1913.

Note:

THIS EXERCISE IS INTENDED TO BE IN THE NATURE OF A TERM PAPER.

PART II

CHAPTER I

CONTROL OF INSECTS

PROFESSOR J. J. DAVIS

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It is becoming more and more evident, even to those not directly in touch with agricultural work, that insects and diseases play a most important rôle in food production. Indeed, the control of this or that insect or plant disease often becomes the limiting factor in profitable agriculture.

Transportation and commerce have brought to us alien plant enemies, thus multiplying our troubles; the continuous and extensive cultivation of the same or related crops and a reduction in the numbers of insect-eating birds and mammals have no doubt been factors of prime importance in increasing insect troubles; and, furthermore, the adoption of cultivated crops in preference to native hosts by insects is a matter of common record and we may anticipate further trouble from this source.

With these increasing troubles new and important discoveries in methods of control are being made and a thorough knowledge of such control operations becomes an essential requisite, particularly for the successful horticulturist, since a great majority of the pests with which he must deal are held in check by proper methods of spraying. This is particularly borne out in an authoritative statement of the horticultural department of the Illinois Agricultural Experiment Station, on the relation of spraying to profitable apple growing, a statement based on facts and experience that "No single operation in apple growing yields such immediate and large returns for the money and time invested as spraying.

In fact, it is a rare season in Illinois when unsprayed apples are marketable, except for cider and evaporation purposes."¹

The damage to all agricultural products of the United States by insects was estimated several years ago at more than one billion dollars annually,² which at the present time is probably double that amount. In other words the insects are responsible for a loss of approximately ten dollars for every man, woman, and child in the United States, and if we considered only the farmers, who bear the bulk of this loss, the amount per farm or farmer would be surprisingly large. This loss (\$1,000,000,000) is four times the annual property loss by fire; more than fourteen times the annual income of all the colleges in this country, and sixty times greater than the funds allotted annually to the United States Department of Agriculture for all agricultural work.

The loss from fungous diseases also amounts to many millions each year, and of this amount it is estimated that 75 per cent could be prevented by spraying.³ The same statement applies equally well to the injurious insects.

In the control of insects injurious to horticultural crops, there are certain important points which should ever be kept in mind. The horticulturist should understand the importance of insect control to profitable horticulture; he should not only know what to use and when to use it, but should recognize the need of efficient spraying, including proper equipment, ingredients, mixing, and applying; he should know the value of an accurate knowledge of the life history and habits of the major insect pests; should be able to recognize the pests and the evidences of their presence, the wisdom of following recommendations for his particular locality or conditions, the relation of good horticultural practices to the insect population, and, finally, the importance of insect control in neighboring home or commercial plantings.

In considering insect control we find it convenient to divide the methods into four groups as follows:

1. *Control by natural enemies.* A method frequently spoken of as the biological control, provided by nature, but which can be assisted to a greater or less extent by proper practices.

¹ Pickett, B.S., et al., Field Experiments in Spraying Apple Orchards in 1913 and 1914, Illinois Agr. Exp. St. Bul. 206, April, 1918, p. 429.

² O'Kane, W. C., Injurious Insects, Macmillan Co., N. Y., 1912, p. 4.

³ Hesler and Whetzel, Manual of Fruit Diseases.

2. *Control by farm practices.* Well-cared for trees, for example, are more resistant to certain borers; clean orchard practices assist in fighting the curculio, etc.

3. *Control by mechanical devices.* Cucumbers and melons are frequently covered with screens to protect them from the cucumber beetle; tomato and cabbage plants are planted with a paper collar to protect them against the cutworm, etc.

4. *Control by insecticides.* At the present time the control of insects attacking horticultural crops by insecticides is by far the most important means of insect control, and this depends absolutely upon an exact knowledge of the structure, life history, and habits of insects.

HOW INSECTICIDES KILL¹

For our purposes insects may be grouped in two classes, according to their methods of obtaining food, that is, whether they have biting or sucking mouth parts. Based on this knowledge insecticides are divided into two groups: (1) those which are placed upon the food eaten by the insects and taken into the stomach with portions of the plant and (2) those which kill directly or indirectly by contact. It is obvious that stomach poisons used to control biting insects like the potato beetle and cabbage worm are not adaptable to the control of insects like aphids which take food only by puncturing plant tissues and sucking plant juices.

Biting Insects. Insects which eat the foliage, such as the potato beetle, cabbage worm, codling moth or apple worm, currant worms, etc., are usually readily destroyed by stomach poisons, such as the various arsenicals, the more common of which are Paris green (copper aceto-arsenite), arsenate of lead, and calcium arsenate. Those most commonly used must necessarily be in the most insoluble form to avoid burning the plant foliage. On the other hand, insoluble arsenicals are not poisonous to insects in their insoluble form, but they are made more or less soluble upon reaching the stomach by the action of the various digestive juices in which condition they may be absorbed through the walls of the

¹Shafer, Geo. D., How Contact Insecticides Kill, Tech. Bul. Mich. Agr. Exp. Sta. No. 11, July, 1911; Tech. Bul. Mich. Agr. Exp. Sta. No. 21, July, 1915. Davis, J. J., How Insecticides Kill, Indiana Farmers' Guide, Vol. 33, Oct. 8, 1921, p. 1199.

stomach and intestines and passed into circulation, resulting in the death of the insect if in sufficient quantity.

Some insecticides may act either as a contact or a stomach poison, and in this group of insecticides may be included hellebore.

Sucking Insects. Insects such as the leaf-hoppers and plant lice or aphids have no cutting jaws as have the insects with the biting or mandibulate type of mouth parts, and since they simply pierce the tissues and suck the juices instead of taking portions of the plant tissues into the stomach they are unaffected by arsenical poisons applied on the foliage. Sucking insects are therefore largely controlled by contact insecticides, so-called because they kill directly or indirectly by contact. While arsenical insecticides are not of use in controlling insects with the sucking type of mouth parts, contact insecticides are sometimes useful against insects with biting mouth parts.

Insect pests in this group (sucking insects) are usually controlled by one of the following methods:

1. *Spraying with a liquid* which kills directly or indirectly by contact. Here we include such common insecticides as lime-sulphur and miscible oil for scale, nicotine solutions for aphids and similar soft-bodied insects, and fish-oil soap for aphids and also as a summer control for scales, etc. These insecticides kill in many ways and their effectiveness is not, as a rule, dependent upon a single property, although one property is usually chiefly concerned, the other insecticidal properties being supplementary or secondary or else there is a direct combination of two effective principles. Contact insecticides may kill by corroding the bodies, they may seal the insect to the plant and prevent development, or suffocate the insect by closing up the breathing pores, but probably more often the death of the insect does not result so much by the direct contact as by the volatile portions of the insecticide entering the breathing tubes, or tracheæ, and being absorbed by the tissues of the body, preventing or interfering with important life activities such as oxygen absorption and assimilation in the tissues. In the case of lime-sulphur, it is now understood that the insecticide kills partly by corroding the body, by sealing the insect to the twig, by softening the scale covering, by hindering the young from settling, and, above all, by suffocating the insect because of oxidation after having been applied, resulting in the removal of oxygen from beneath the scale covering.

2. *Dusting with powders* for the control of sucking insects has been done for many years, but only recently has a contact dust, practical for use on large acreages and thoroughly effective, been found. There is reason to believe that contact dusts will prove to be a most effective means against certain pests, particularly such as are more difficult to reach with liquid sprays. Insect powder or pyrethrum has long been known as an effective contact poison when applied as a powder. More recently the nicotine dusts have come into use and offer large possibilities.

3. *Poisonous gases and vapors* are effectively used to control insects under certain conditions. Thus nicotine fumes are used to destroy certain greenhouse insects and hydrocyanic-acid gas is commonly employed in greenhouses, in mills and storage plants to destroy pests attacking grain and other stored products, in specially built boxes or bins to destroy scale on nursery stock and under tent coverings to destroy fruit tree pests. Fumigation is an ideal method of control where practicable because the gas if properly generated and in proper containers reaches every portion of the plant in sufficient quantity to kill the insects while it is sometimes difficult, if not impossible, to hit every insect or every portion of the plant with a liquid spray.

4. *Heat* is the most efficient insecticide known, but is adaptable only for a few situations. Thus it is commonly employed in greenhouses to destroy soil-inhabiting insects, steam heat being employed under such conditions, and also in mills, to destroy mill-infesting insects, the dry heat being used in this case.

5. *Repellants* are sometimes used to protect plants from both biting and sucking insects, but they are not, strictly speaking, insecticides since they do not destroy the insect, but rather make the plant unattractive or repellant and in this way protect it from injury. There are, however, several very well-known examples of control by the use of repellant sprays, noteworthy of which are the control of the potato leafhopper and various flea-beetles by the use of Bordeaux mixture, which is a common repellant for many different kinds of insects.

Other Considerations. There are certain limiting factors which should be recognized with certain insecticides. They are (1) insecticidal properties or in more general terms we may say the killing properties; (2) effect on foliage or the plant in general under varying weather conditions, etc.; (3) physical properties, such as

adhesiveness, spreading, stability, reaction with other insecticides, consistency, etc.; (4) repellent or attractive properties; and (5) cost. As already mentioned, it is not only necessary to use the insecticide best adapted for the control of any especial insect and to see that it is properly mixed, but it is essential that the operator be provided with suitable spraying equipment to make his applications, and that the applications be made thoroughly. Frequently, too often in fact, the lack of control is due not so much to improper materials, but rather to inadequate spraying equipment and lack of thoroughness in application.

Insect control is based largely or entirely on our knowledge of the structure, life history, and habits of the individual insects. For the control of certain classes of pests, either because of life habits or because of prohibitive costs of spraying or other insecticidal operations, we are dependent on general or special farm or orchard practices, and it is generally recognized that the better farm practices, methods which generally give the best yield, likewise have the greatest influence in preventing insect losses. Certain insects can be reached effectively by mechanical devices, for example, grasshoppers controlled by grasshopper-catchers, chinch bugs by the use of the combination barrier line and post-hole traps. Certain other insects are most effectively controlled by the artificial introduction and use of natural enemies. Another factor in insect control which may be mentioned is the development of insect-resistant varieties of plants. This phase of plant protection is not of very great importance at present, but the resistance of certain varieties to insect attack is not unknown. Thus certain varieties of apples are less subject to scale injury, certain types of corn resist attacks of the earworm, chinch bug, etc.

In studying insecticides and methods of application one must not only remember and keep in mind the general axioms already referred to, but should remember that for the best results in actual practice it is necessary that one be familiar with the more important kinds and to have a general knowledge of the life history of the insects, so as to know when, why, and where to spray to get the best results.

CHAPTER II

CONTROL OF PLANT DISEASES

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The control of infectious plant diseases, most of which are caused by bacteria or fungi, presents to the grower of plants a most complicated problem. Like the human species, almost every crop is subject to a number of diseases and usually there is no cure-all for these troubles, but each disease must be understood thoroughly in order to be combated intelligently. The underlying principle in plant-disease control is that of prevention rather than cure. As a rule the grower is interested in the crop as a whole rather than the individual plant.

The general methods of the control of parasitic plant diseases may be grouped for convenience under five headings:¹ (1) Exclusion, (2) Extermination, (3) Inhibition, (4) Protection, (5) Disease resistance.

EXCLUSION

Certain diseases may be controlled by exclusion of the parasite from regions or fields where it is not yet present. On a large scale this is illustrated by state and national quarantines against the importation of diseased seed and nursery stock. The chestnut blight and white pine blister rust were introduced with foreign nursery stock, cabbage black rot comes in every year on European seed, and the potato wart and powdery scab diseases entered this country with imported seed tubers.

Apple blotch is introduced into new orchards on nursery stock of the susceptible varieties and peach scab is carried far and wide in this manner. The two serious soil diseases, cabbage yellows

¹ This is the classification used in the Department of Plant Pathology, University of Wisconsin.

and tomato wilt, are largely spread by the transport and use of diseased transplants and could be excluded by the exercise of proper precautionary measures against the use of such transplants. Potato mosaic and leaf-roll are introduced with diseased seed tubers and can be avoided only by the use of seed from fields which did not contain these diseases. Bean blight and anthracnose are carried with the seed and it is a difficult matter to secure seed free from these troubles.

EXTERMINATION

Total extermination of the parasite in the soil, in or on the seed or vegetative reproductive parts, or on the plant itself is a successful means of combating many diseases. The application of this principle on a large scale is illustrated by the citrus canker campaign in Florida, which consisted of the wholesale destruction of citrus trees affected with citrus canker and the consequent total elimination of the disease from whole districts.

Soil disinfection as a control for root-knot, tomato wilt, lettuce drop, and seed-bed troubles also depends for its effectiveness upon the extermination of the parasitic organisms in the soil by steam or by formaldehyde.

Surface disinfection of seed oats with formaldehyde controls the oat smut, hot-water treatment of seed wheat controls the two wheat smuts, and surface disinfection of potato seed tubers with formaldehyde or mercuric chloride solutions controls scab and black scurf. Certain diseases of cabbage, cucumber, tomato, tobacco, and cotton are also controlled by seed disinfection. Nursery stock may be dipped in a fungicide to kill adhering spores or bacteria.

Extermination of the parasite is also accomplished in spraying with potassium sulphide for the superficial powdery mildew of gooseberries and in dusting or fumigating with sulphur for the similar disease of roses, since the powdery mildews live on the surface of their hosts (the plants attacked), and are thus fully exposed to the action of the poison. The same object is also accomplished in the dormant spraying of peach trees with lime sulphur to control leaf curl, since the spores causing this disease hibernate on the bud scales and are killed outright by the spray material.

INHIBITION

Inhibition of the prevalence or destructiveness of parasites is accomplished usually by certain cultural practices and precautionary measures based largely upon the principles of sanitation. To guard against an undue accumulation of certain parasitic organisms in the soil, crop rotation is especially necessary with such crops as watermelons, cucumbers, potatoes, beans, tomatoes, and cabbage. Residues of one crop should not be used for fertilizer for a similar crop and it is noteworthy that many parasites are not killed by passage through animals.

Another method of inhibiting parasites is that of destroying diseased parts of the host, such as peach brown rot mummies, black rot cankers in apple trees, and hold-over fire blight cankers in pear trees which harbor the parasite during the winter and serve as early sources of infection in the spring.

Some diseases cross over from wild or worthless plants to economic crops and the destruction of such sources of infection is important in the control of stem rust of wheat (barberry eradication), apple rust (eradication of red cedars), lettuce downy mildew (eradication of wild lettuce in greenhouses), and cucumber mosaic (eradication of milkweeds). In fact apple rust infection comes only from the red cedar and its control is readily accomplished by eradication of these trees within a radius of a mile, since the spores are not likely to be blown that distance in great numbers.

Another method of inhibiting a disease is to avoid spreading it by certain cultural practices as in working with vegetable crops when these are wet with dew or rain, pruning greenhouse tomatoes, overhead watering of greenhouse crops, and careless pruning of apples and pears where fire blight is present.

Parasitic activity may also be inhibited by alterations in the soil reaction as in the case of cabbage club-root control by liming the soil and potato scab control by adding sulphur to the soil.

By destroying part or all of the parasitic spores in the soil immediately surrounding the freshly planted seed or on the surface of the seed, certain diseases which depend upon seedling infection may be controlled. Thus, onion smut is prevented by a formaldehyde drip on the seed drill and stinking smut of wheat in the Northwest may be successfully combated by dusting the seed grain with powdered copper carbonate.

By variation of the planting date, certain diseases may be rendered less destructive. For example, in the Northwest, very early or very late seeding of the wheat reduces the smut loss.

Cantaloupe wilt and many mosaic diseases are mainly insect-disseminated and control of the carrier insects is important in such cases.

Fruits and vegetables are really alive and the storage rots may be truly considered as diseases of these living plant organs. There are a number of methods of inhibiting the inception and destructiveness of storage rots based upon the following principles:

1. Careful picking and handling prevents wounds and bruises through which rot-producing organisms may enter. Thorough drying of all wounds also retards parasitic invasion.

2. Only disease-free products should be stored, since field diseases open the way for storage rots. For example, apple scab spots are very likely to be invaded by pink mold rot in storage.

3. Proper regulation of the temperature, humidity, and aeration during storage not only prolongs the storage life of the product, but the low temperature prevents or greatly checks the growth of the rot-producing fungi and bacteria, and a low humidity, by making the tissues drier, renders them less subject to rot infection.

PROTECTION

By protection is meant the application of a protective poisonous substance to the exterior of the plant before it has become infected, and the summer sprays or dusts are applied with this end in view. All infection of plants by parasitic organisms comes from the outside, and the theory of a protective spray or dust is to have a coating of a poisonous substance on the susceptible parts of the plant so that a fungous spore, alighting on this coating, is killed before it has an opportunity to cause infection. When there is enough moisture present, such as a minute droplet of dew, to enable the spore to germinate and invade the host tissue, enough of the poisonous substance will be dissolved in the water to kill the spore. In all spraying or dusting operations, therefore, it is evident that all susceptible parts of the plant must be thoroughly covered and that as growth occurs frequent applications will be necessary to keep the new growth protected. Furthermore, it is necessary to know during what period the disease is spreading so

as to have the spray or dust present before infection has occurred. No amount of spraying will check the growth of a fungus once it has gained entrance to the inner tissues of the leaf or fruit.

Summer spraying with such protective fungicides as lime-sulphur or Bordeaux mixture is an essential measure of control for apple scab and blotch, peach brown rot, and cherry leaf-spot, and early spraying with lime sulphur controls raspberry anthracnose. Spraying is also necessary to control the late blight of potatoes in the northern potato sections. Other truck crops which may be profitably sprayed for disease control are watermelons in the South and tomatoes in the East. The advisability of spraying truck crops depends somewhat upon the region and the prevalence of certain diseases, since under certain climatic conditions it will pay to spray for these diseases while otherwise it may not. Dusting with a mixture of sulphur and lime or copper sulphate and lime is being recommended as a substitute for spraying in certain cases and the relative merit of dusting versus spraying is a much debated question.

Other examples of disease control by the application of a protective coating to the healthy host tissues are the treatment of pruning and tree surgery wounds to prevent the entrance of wood-rotting fungi and the use of Bordeaux paste on the freshly cut ends of stems of watermelons to prevent the entrance of the fungi that cause stem end-rot during shipment.

DISEASE RESISTANCE

Many plant diseases may be successfully avoided by the use of varieties or strains resistant to the particular disease in question. This is a relative term and as a rule applies to one disease only. No varieties or strains are resistant to all diseases, but when a certain disease becomes so prevalent as to be a limiting factor generally, the discovery of disease resistance is often the only solution of the problem.

Where the soil trouble, cabbage yellows, is present, the use of yellows-resistant strains which have been developed by careful selection must be practiced. Wilt-resistant strains of tomatoes are available. Other examples of disease-resistant crops in general use are the yellows-resistant variety of celery, the rust-resistant asparagus, and the wilt-resistant flax.

Knowledge of the relative susceptibility of apple varieties to diseases is indispensable to anyone starting a new orchard. In the blotch region, blotch-free varieties might as well be used. Where red cedars are abundant the Wealthy will be badly rusted. The Kieffer pear, because of its partial fire blight resistance, is supplanting other varieties.

CONCLUSION

In this fragmentary survey of the extensive subject of plant disease control it should be evident that in many of the various operations and processes involved an experience in applied chemistry and engineering, such as the preceding exercises afford, should be invaluable to all students planning to engage in any branch of agriculture. The preparation of the various germicides and fungicidal sprays and the intelligent use of these, as well as the many other methods of plant disease control, must constitute an essential part of agricultural practice if high yields are to be maintained.

CHAPTER III

SPRAYING MACHINERY

A STUDY of spraying machinery is of tremendous importance to everyone interested in the profitable production of horticultural crops. In many instances thorough spraying is essential if a profit is to be realized, and effective spraying can only be done with carefully selected machinery.

Spraying machines are on the market in styles and types so numerous as to bewilder the inexperienced buyer, and he is likely to succumb to the first salesman who happens along, without carefully considering the suitability of the purchase. It is not the purpose of this discussion to recommend any particular make or to describe in technical detail the construction of these machines, but rather to point out the good and bad features which make them useful or undesirable. The size of sprayer to buy and the daily output which may be expected from it will be considered in the chapter on "Miscellanies."

If a spraying machine built ten years ago could be exhibited and compared with the latest model by an expert, the improvements and changes would be even more numerous and impressive than a similar comparison of automobiles. Men who devote their best years and entire attention to this work are keen, skillful, and progressive. Many of them follow the field problems in spraying closely and some have farms where they gain first-hand information regarding growers' troubles. As a rule such men are naturally the most successful manufacturers.

Making spraying machines is a radically different problem from making well pumps or other outfits which transfer water only, so it does not follow by any means that a successful maker of well pumps will also build good spraying machines. To be successful in this field he must recognize that pumps and engines designed for stationary work are not the lightest in weight for the power they develop. On high-pressure sprayers, engines are installed which develop at least four times the horsepower per

pound weight found in stationary or semi-stationary types. Cast iron is very heavy in proportion to its strength but may be used in the construction of spray pumps except for wearing surfaces coming in contact with spray materials. Here the corrosive action of spray materials causes more rapid wear on cast iron than on brass or bronze. Another exception to the use of cast iron is in shade tree sprayers where extremely high pressures require metal of great tensile strength, and in this instance the weight of cast iron would prohibit its use. Lightness, strength, and durability in these parts of the pump are obtained by using bronze,—phosphor bronze being used for shade tree sprayers. The importance of having the working parts and the tank of the outfit made of non-corrosive materials cannot be over-emphasized, and in the discussion to follow, comment on this point will be repeatedly made in considering certain outfits. Spray mixture tanks made of wood are more durable and popular on power, tank, and barrel outfits than metal containers. On various styles of hand sprayers, wooden tanks cannot well be used, so they are made of tin, galvanized iron, sheet steel, and brass, named in order of cost. The brass tank is the lightest, and the cheapest in the end because of its durability, but some growers demand an outfit with a lower initial cost, and the maker provides it. As with a tank, so with the entire spray outfit—buying a cheap one is not usually economy, but shortsightedness.

In general, the requirements for a good spraying machine are that it should be as light as possible so as to be conveniently handled under trying working conditions, as on hilly or soft ground. It should be constructed with a minimum number of parts requiring attention, and so placed that they may be easily repaired or replaced when necessary. The outfit must be built strongly enough to withstand the ordinary emergencies in the field. Strength and durability should not be sacrificed for the sake of lightness, but when the three are consistently combined a very important phase of manufacture has been accomplished. To sum up, lightness, simplicity, accessibility, strength, efficiency, and durability are the factors which both maker and user are seeking in spraying machines, and their efforts and desires are constantly being rewarded.

SPRAY PUMP PARTS

The important parts of a spray pump which may be found on practically all types are the pump cylinder, plunger, valve, valve seat, air chamber, and agitator.

Cylinders. Cylinders come in contact with spray material, and in addition to the wear due to friction there is also liability to wear due to the action of spray materials if they are not made of non-corrosive material. Brass or bronze are the materials most commonly used in cylinder construction. In most pumps the cylinder consists merely of a brass tube, but one type is made up of a cast-iron sleeve lined on the inside with a brass cylinder. One manufacturer uses a cast-iron cylinder lined inside with porcelain and this design has proved to be one of the most desirable and the least affected by spray materials. Another make uses a cylinder constructed entirely of iron, but as all the wear comes on the packing which lines a portion of the cylinder this type is satisfactory.

Plungers. The plunger performs a most important function of the pump in forcing the spray material on to the nozzle. With each make the plungers are so constructed that they will carry only a certain type of packing and no other can be substituted. Various materials are used for packing, such as hemp, candle wick, canvas, asbestos, leather, and rubber composition. The first four materials are treated with oil, tallow, paraffin, or graphite to keep them soft and in order to make the plunger work easily. Plungers so constructed that the packing can be easily tightened or renewed are most desirable. In some pumps it is possible to tighten the packing without removing the plunger from the cylinder and this is a desirable feature. All wearing parts of the plunger which come in contact with spray materials should be made of brass or bronze. An exception to this is found in a well-known make where the plunger is made of hardened steel and carries no packing, but this type of plunger must be renewed each year. Sometimes where the acreage assigned to the sprayer is exceptionally high, the plunger may need to be renewed three times, but only when the sprayer performs 140 days' work in a season. This is more work than some outfits are required to do in five years.

Valves. There are three general types of valves used in spraying outfits. They are disk, poppet and ball types as illustrated in Fig. 19. The disk and poppet valves are quite similar except that the former is always flat-faced and has no rod or wing guides. Disk valves are rarely used at the present time. All types are usually made of hard bronze, but steel or rubber are sometimes used.

Poppet valves may be either flat or bevel faced and with rod or wing guide. *B* of Fig. 19 is a flat-faced poppet valve with a rod guide. *C* and *D* are two kinds of poppet valves with beveled face and wing guides. The ball valve is simply a ball as shown in *E* and *F*.

The ball valve is the type most generally used in garden and orchard sprayers. It is cheap, simple, seats quickly and effectively, wears evenly, and offers little resistance to the passage of liquids.

In the large-capacity shade-tree sprayers, a large poppet valve is used. Large valves are important in machines of this type and the weight of a ball valve of sufficient size would be prohibitive to efficient operation.

It is of special importance that valves be accessible enough to be easily cleaned when clogged with twigs, leaves, gaskets, or other foreign material, and that they may be easily replaced when worn. Growers are finding that valves wear out more quickly to-day than formerly. This is due to the higher pressures adopted since the introduction of the gun, the greater friction through the valve and the harder rebound of the ball. Spray machines also deliver more spray mixture in a day and this contributes to the amount of wear.

Valve Seats. This part of the spray pump also receives a great deal of wear and therefore should be made of some hard alloy not corroded by spray materials. However, it is preferable to have it of slightly softer material than the valve when it can be easily and cheaply replaced, so that most of the wear will come on the seat. Bronze is most often used but some are made of rubber composition. In some pumps the valve cage and valve seat are in one piece as shown in *F*, Fig. 19, but as a usual thing they are separate. The valve seats should be so constructed that they may be replaced when worn. Those which screw out should be avoided because they are difficult to remove. Seats

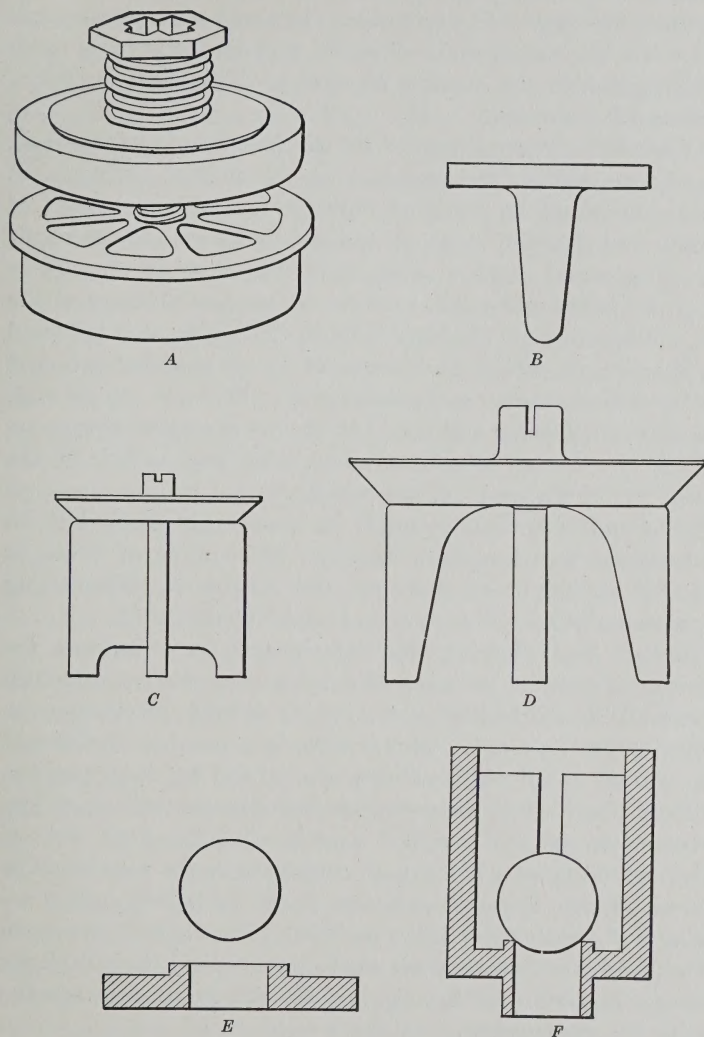


FIG. 19.—Types of Valves.

A—Disk Valve
 B—Flat-faced Poppet Valve with Rod Guide
 C—D—Bevel-faced Poppet Valves with Wing Guides. *D* is Used in Shade-tree Sprayers.
 E—F—Ball Valves. *E* Shows the Ball and Seat. *F* Shows the Valve Cage and Seat Cast in One Piece.

that are made thick enough so that they may be reground when worn and used again are preferable. In some makes when one side is worn the seat may be reversed and the other side used, thus giving double the amount of service. This type is known as a reversible valve seat.

Air Chamber. The purpose of the air chamber is to maintain as evenly as possible the pressure at the nozzle. Without it the pressure would be obtained only on the working stroke of the pump and it would range all the way from zero to the maximum. This would cause a severe and sudden strain on various parts of the pump and would give a very uneven pressure at the nozzle. Where the air chamber is used, the liquid as it is forced out of the pump enters at the bottom of the air chamber and as it rises it compresses the air at the upper part. When so compressed, the air acts as a cushion and exerts an almost constant pressure on the liquid in the air chamber. The inlet and outlet to the chamber should always be at the bottom.

This chamber is usually made of heavy cast steel, but on bucket pumps and knapsack sprayers it is made of brass or bronze. It should be of good size and capable of withstanding high pressures which will vary with the size of the outfit.

Agitator. The effective materials in any spray mixture are not always in solution, but are held in suspension and consequently the materials should be kept well mixed in order to secure an even distribution on the plant. This is done in a number of different ways. In the small outfits which are carried by the operator, agitation is provided by the motion of the operator while spraying. The barrel pumps are equipped usually with the dash type of agitator consisting of a brass plate connected to the pump handle by a rod. Other types of agitators found in barrel pumps are swinging and revolving wooden paddles. The chief objection to wooden paddles is that they are easily broken, and the steel bolts become so corroded that they are very difficult to remove when the necessity for repair arises.

In power outfits the propeller type is popular and efficient. The effectiveness of the agitation with this type depends on the number and size of blades on the shaft, their arrangement, and the speed at which they operate. Three wings or blades for each propeller are most often used and one propeller is located near each end of the tank. Some outfits are geared to run the agitator

at 100 revolutions per minute, but the speed should depend on the size and arrangement of the blades. In general this type is light, durable, efficient, and easy to take care of.

In a power sprayer of recent introduction a method of agitation formerly discarded is again being used. It consists of a perforated pipe located near the bottom of the tank through which the mixture is pumped and forced in various directions in a series of jets which provide the agitation. The objection formerly found with this type was that it had a tendency to clog. Though only a portion of the jets might actually be clogged, yet the entire system ceased to function. If this happened when the tank was filled with spray mixture, the added difficulty of disposing of the mixture arose. Since this method has again been adopted, the effectiveness of the new design will be watched with great interest. When the jet agitator is used a part of the spray solution is returned to the tank, and it is obvious that a pump of greater capacity is needed to deliver the same amount of material at the nozzle.

In some power machines the agitator works only when the pump is operating. If the outfit must be moved to another location while the tank still contains spray mixture, it is highly desirable that the agitator be kept in motion. Shade tree sprayers are equipped with a paddle type of agitator driven directly from the engine by a gear transmission which keeps the mixture in suspension even though the pump is disengaged. These agitators consist of two wooden strips attached to extensions from the agitator shaft and nearly as long as the tank. They revolve slowly and churn the mixture thoroughly, passing within a fraction of an inch of the bottom of the tank. They are a very efficient agitator and have been adopted on certain fruit and truck sprayers.

When an agitator stops, arsenate of lead and other heavy, sticky materials will quickly settle to the bottom of the tank. When it resumes operation, most of the sediment remains on the bottom, for the function of an agitator is, not to suck sediment up from below, but to keep materials in suspension.

Some manufacturers and all buyers of spray outfits should study the efficiency of the agitator. Tests carried on by Professor A. L. Lovett of the Oregon Experiment Station, Corvallis, Oregon, show that moderately violent agitation improves the physical qualities of lead arsenate when extremely coarse particles are present. During vigorous agitation, the lead is rapidly separated

into a uniform, finely divided condition. In this form the poison adheres best to the sprayed surface, and is most efficient.

TYPES OF SPRAY OUTFITS

Many types of spraying outfits are now offered by manufacturers in order to satisfy the demands of growers with orchards of widely varying acreages and gardens and vineyards having peculiar requirements. One manufacturer alone sells eighteen different types of sprayers at the present time.

There are various ways in which spray outfits may be classified.

The classification which we shall adopt for the sake of discussion contains eight groups, as follows: Hand Atomizers, Com-

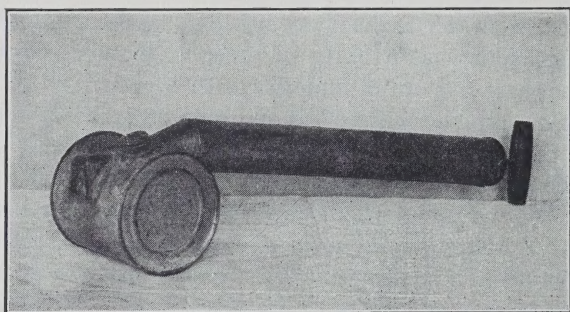


FIG. 20.—Atomizer.

pressed-air Sprayers, Bucket Pumps, Knapsack Sprayers, Barrel Pumps, Tank Pumps, Traction Sprayers, and Gasoline Power outfits.

Hand Atomizers. This group represents the smallest type of sprayer used in pest control. Where only a few small plants are to be treated it will prove satisfactory. Most atomizers will hold one quart of liquid. They are not true spray pumps, but are composed of an air pump fastened to a small container which holds spray material. On the compression stroke of the plunger a current of air passes across the end of a small tube extending to the bottom of the container and this current of air draws the spray up through the tube and breaks it up into a fine mist as it leaves the opening. Some atomizers are properly made of brass; others made of tin or galvanized iron are also offered for sale.

In some instances corrosion is avoided in atomizers by using a mason jar or some other glass container for the spray mixture. The only agitation secured is from the vigorous movement obtained in operation.

Compressed-air Sprayers. This type cannot be considered a true spray pump because it pumps air instead of liquid. The pump is clamped into an air-tight tank which is filled two-thirds to three-fourths full of spray material. Air is then pumped into the tank until the mixture is forced out into the nozzle. Before the liquid has all been forced out of the tank it will be necessary to pump up the air three or four times at least. Compressed-air sprayers are carried by means of a strap over the shoulder, agitation being provided by the movement of the operator.

The capacity of this outfit is from 3 to 4 gallons. Some people prefer it to other small hand outfits because they do not wish to pump while spraying. The pressure fluctuates

widely because it decreases as the liquid is forced out and must be renewed by working the air pump. Because of the pressure exerted on the outfit it should be made stronger than other hand outfits. Galvanized sheet steel is strong, but less durable than brass.

For the home garden or the spraying of a limited amount of low-growing plants this outfit may be used, but it does not give the constant pressure and the steady distribution of spray secured with the knapsack sprayer or the bucket pump.

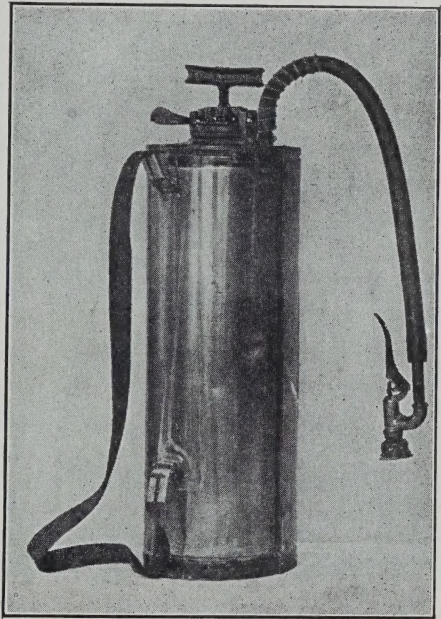


FIG. 21.—Compressed-air Sprayer. Is Carried Over the Shoulder.

Compressed-air Sprayers of Large Capacity. There is very little information in published form concerning the operation and efficiency of compressed-air sprayers as used in commercial orchard work. To a limited extent this type has been used in commercial orchards up to three or four hundred acres in size. The success attained with this type has been variable, depending on the selection of equipment and, as with other outfits, upon the



FIG. 22.—Compressed-air Sprayer. For Spraying Orchards and Vineyards. It is Light and has no Complicated Machinery. Pressure Often Varies and the Agitation is Not Satisfactory.

particular design and efficiency of the machine used. Questions arise concerning this type of outfit frequently enough so that a discussion of its operation, as well as its advantages and disadvantages, may well be considered here.

The outfit consists of two specially built tanks of nearly equal size, one for receiving the charge of compressed air, the other for the liquid. These tanks may be connected with pipe or hose and air may then be released from the air tank to force the liquid out of the other tank to the nozzle. A few valves are necessary, also

a lead of hose, with the usual connections for spraying and this completes the field sprayer.

Tanks of 60-gallon capacity are frequently used and when mounted on a two-wheeled cart make a good light rig for rough and hilly ground. One horse can take them almost anywhere, and for peach orchards or wherever towers are not necessary in spraying this type is preferable. Larger tanks of 120-gallon capacity can be mounted on any ordinary farm wagon by strapping them to two 4×6 bunks. These should be so made that the air tank is placed over toward the left side of the wagon so that the solution tank of greater weight is located near the center. Other methods of mounting these tanks may be used; this one is merely suggested. A spray tower may be mounted above this outfit.

The equipment at the supply or loading station consists of an air compressor, engine, a tank for preparing the spray mixture, and a pump or tank to supply the water.

Compressors are made in different sizes. The larger type with the aid of a station air tank will furnish air pressure for a 60-gallon tank in about 3 minutes while it takes 5 minutes for a 120-gallon tank. The smaller compressor will require 8 minutes for a 60-gallon tank with the aid of the station air tank and 12 minutes for the 120-gallon size. Without the station air tank it will take about twice as long to generate the proper air pressure. Perhaps the mistake most often made in securing equipment for compressed-air outfits is to install a compressor which lacks capacity. Another mistake is lack of provision for proper agitation. Some growers feel that the compressor should have sufficient capacity to enable recharging the air tank in 3 minutes and that agitation should be secured by passing the air, which maintains the pressure, through the liquid.

The advantages as claimed by growers for this type of outfit are, that no engine need be taken into the orchard, relief valves and plungers are not necessary, there is no delay in beginning work in the orchard due to engine trouble, the repairs are exceedingly small, and the outfits will outlast many times any rig that must pump spray mixture. The weight of a compressed-air sprayer is much less per gallon capacity, and the outfit may therefore be taken where other sprayers cannot go.

A disadvantage frequently raised is that the compressed-air outfit requires expensive equipment for generating air pressure

and that it is therefore suited only to large orchards where several outfits are required. While this is true when it is used by only one grower, a community of orchardists may use a central station adequately equipped to load a large number of tanks.

In spite of the many apparent advantages of compressed-air sprayers, including the low overhead in operation, its use is not on the increase, but rather, if anything, decreasing. Some growers who have used them for years are now replacing them with gasoline engine outfits. Perhaps this is due in part to the change in nozzle capacity and requirements. With nozzles of small capacity, pressures of 125 to 150 pounds were satisfactory. With

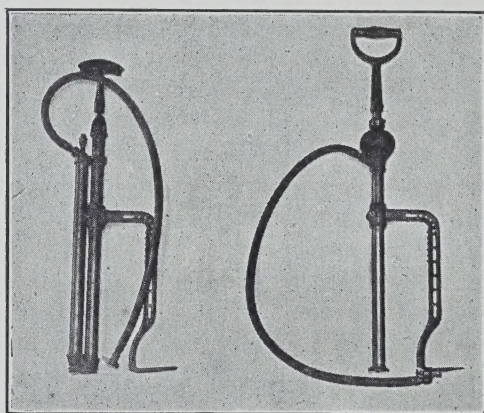


FIG. 23.—Bucket Pumps. The One on the Right is a Double-acting Pump

the advent of the gun, cluster nozzles, and others of large capacity, growers began to increase the output of their men each day and operating large capacity nozzles with a pressure of 150 pounds or even 200 was unsatisfactory. Probably the average working pressure obtained with compressed air will not exceed 150 pounds.

Another way in which such sprayers fail to measure up to the standard of gasoline power outfits is in agitation. Some growers have given this as the main reason for disposing of their outfits.

If these two weaknesses can be eliminated the compressed-air sprayer will again become popular for it has a number of obvious advantages.

Bucket Pumps. This is a cheap and satisfactory pump for spraying gardens or a few shrubs and small trees. Any bucket

may be used as a container for the liquid and most pumps are clamped to the bucket to make them steady when operated. The tank capacity of these outfits varies with the size of the vessel, but is usually from 2 to 4 or 5 gallons.

Most bucket pumps are single acting, that is, they force liquid on one stroke only, but a few discharge liquid on both strokes and are known as "double acting." The majority of these pumps are equipped with air chambers which vary greatly in size. Not every design of bucket pump is equipped with an agitator, but a

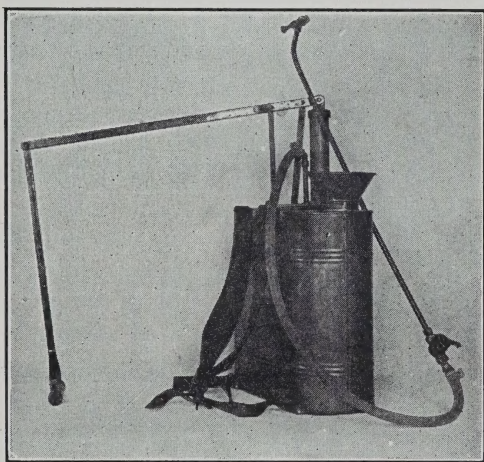


FIG. 24.—Knapsack Sprayer. All Parts Coming in Contact with Spray Mixtures are of Brass.

brass plate attached to the handle affords agitation in some instances and in others a jet of liquid is forced from the base of the pump. Unlike most other hand outfits, bucket pumps are nearly always made of the right material, which is brass.

Knapsack Sprayers. In range of usefulness the knapsack sprayer corresponds very closely to the hand type of compressed-air sprayer and may be used on low-growing crops or on small trees when a stepladder is available. The tank has a capacity of about 4 gallons. An outstanding advantage of this type over the bucket pump is that the operator may move about with the outfit while spraying. A decided advantage which it has over the compressed-air sprayer is that a fairly high and uniform pressure

may be maintained by means of a pump which is in constant operation. Uniform pressure insures an even coating of spray on the plant and there are no delays devoted to pumping air as in the case of the compressed-air type.

The sprayer consists of a force pump with a good-sized air chamber fitted to a special tank designed to be carried on the back of the operator. Agitation is thorough and provided by a brass plate which moves up and down with the pump handle.

The disadvantage with this outfit is that it means real work to operate it for any length of time. Considerable weight must be carried on the shoulders and in warm weather moisture condenses on the outside of the tank, which, added to the slopping, is a source of discomfort to the operator. When its capacity and cost are compared with other outfits it seems rather expensive, yet it is actually a good purchase for its special purposes.

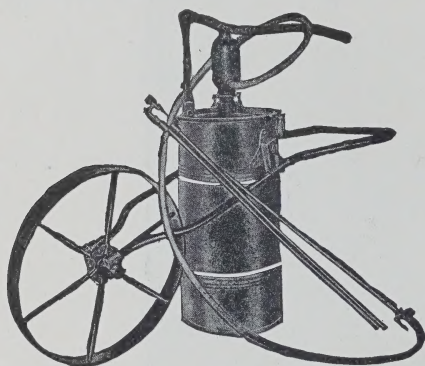


FIG. 25.—Barrow Sprayer. A Large Wheel Like this One Makes the Outfit Easier to Handle in Soft Ground. This Pump Gives Satisfactory Service for Small Operations.

Barrel Pump. The barrel sprayer outfit is the smallest hand sprayer which will prove satisfactory for spraying anything more

than a very few trees. Its tank capacity is 30 or 50 gallons as a usual thing, although special tanks are designed of 100-gallons capacity. The rate of discharge is from 50 to 70 gallons per hour and the pressure maintained should be at least 100 pounds and preferably 125.

Barrel pumps vary in design, construction, and durability as widely as any type of outfit on the market. Those which conform to the specifications laid down in the introduction to this chapter give greatest satisfaction and are cheapest in the end. Under features of accessibility it would be well to call attention to the importance of construction which allows the pump to be removed easily and quickly from the barrel. In some makes the valves

are so accessible that it is only necessary to remove one part in order to reach both valves. Another desirable feature found in

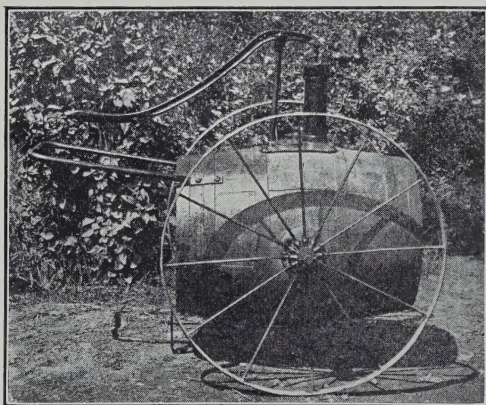


FIG. 26.—Barrel Cart Sprayer. Pump Mounted on Side.

some pumps is that the plunger packing may be tightened without removing the pump from the barrel. Barrel pumps may be

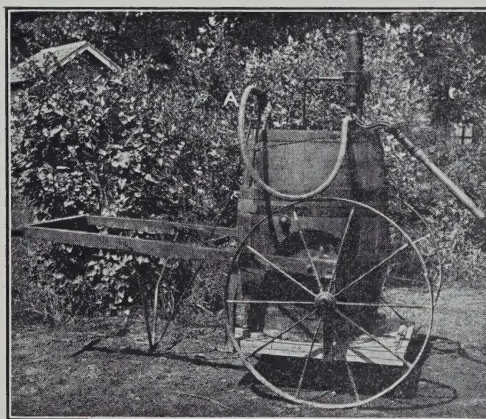


FIG. 27.—Barrel Cart Sprayer. Pump Mounted on End. Outfit Equipped with Nozzle Separator at A.

mounted either on the side or on the end, the former being preferable because of the lower center of gravity.

Tank Pumps. This is the largest type of the hand pumps and is intermediate in capacity and rate of discharge between the barrel and the smallest power outfits. This pump is known by various names, as the horizontal or vertical, double-acting or single-acting. The terms horizontal and vertical refer to the position of the pump cylinders. In a double-acting pump each stroke of the handle forces liquid to the nozzle—with a single-acting type only every other stroke actually pumps spray material. The various designs of these pumps are operated in one of two

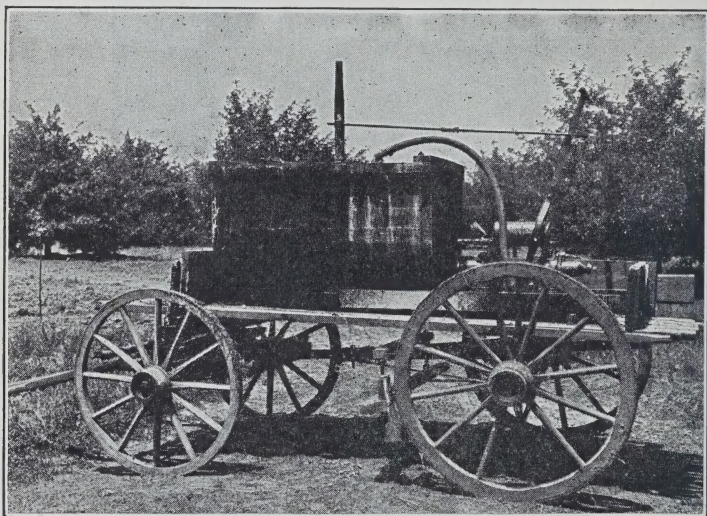


FIG. 28.—Tank Pump Sprayer. This Pump is of the Two-cylinder, Horizontal, Double-acting Type. Spray is Transferred to the Pump by Means of the Suction Hose. Agitation is Provided for by a Swinging Paddle which is Connected to the Pump Handle by a Steel Rod.

ways; some with a forward and backward movement, and others with an up-and-down motion. The pump is separate from the tank and may be connected to any convenient size, the usual variation being from 150- to 250-gallons capacity. Almost any design of tank pump has greater leverage than the average barrel pump and a higher pressure may be maintained than with the barrel outfit. Quite often it happens that a pressure of 50 pounds greater than the usual pressure secured for a barrel pump may be maintained with a tank pump without any greater expenditure of effort.

The ease with which a pump of this type operates depends to a considerable degree on the length of the handle. In some designs the handle connects to the pump at a point very close to its base. By this means the operator may work the handle at the usual convenient height, yet because of the manner in which the handle is attached the leverage is greater and the work correspondingly easier. Tank pumps will discharge about 80 gallons of liquid per hour at 125-pounds pressure when the right type of labor is available, and in emergencies one may pump enough liquid to supply two leads of hose, each carrying a small disk nozzle or one lead of hose with a two-cluster disk nozzle.

Owing to the amount of labor involved none of the hand outfits are popular in the commercial orchards and the tendency in recent years has been more and more away from these useful outfits. However, the man who owns an orchard not yet in bearing may get along very nicely with a barrel pump for smaller acreages or a tank pump where the acreage ranges between 20 and 40. The limiting factor in all these instances is to have satisfactory labor. When the trees are young, the amount of material required per tree is very small and the number of sprays applied is also less than when the trees are in bearing. The man who is limited in capital and must economize will find that where good labor is available a considerable saving may be effected by getting along with hand outfits.

The smallest power sprayer costs more than twice as much as a tank outfit. It can be used in a young orchard only a very few working days in the season yet it ties up a considerable amount of money. In many instances, therefore, an actual saving can be effected in using hand outfits. In spite of the economy which hand outfits would effect, growers are in the great majority of cases buying power outfits because they are seeking labor-saving methods of doing the work, and perhaps they expect to place greater reliance in gas engines than in additional farm help.

One of the chief objections to tank pumps is that agitators are not usually provided. The fact that the pump is separate from the tank makes it difficult to provide this feature. Where it is installed, a paddle is suspended in the tank and connected by a rod to the pump handle. This adds a little bit to the power necessary to operate the pump, but the agitation secured makes this feature highly desirable.

Suction hose is used to transfer the spray mixture from the tank to the pump. The usual features of accessibility, durability, etc., should be kept in mind when purchasing this type of pump.

Traction Sprayers. Sprayers of the traction type include any design which secures its power from the motion of the wheels by which it is conveyed. This type is not desirable for orchard spraying because sufficient pressure cannot be obtained by driving from one tree to another to spray each tree properly. It

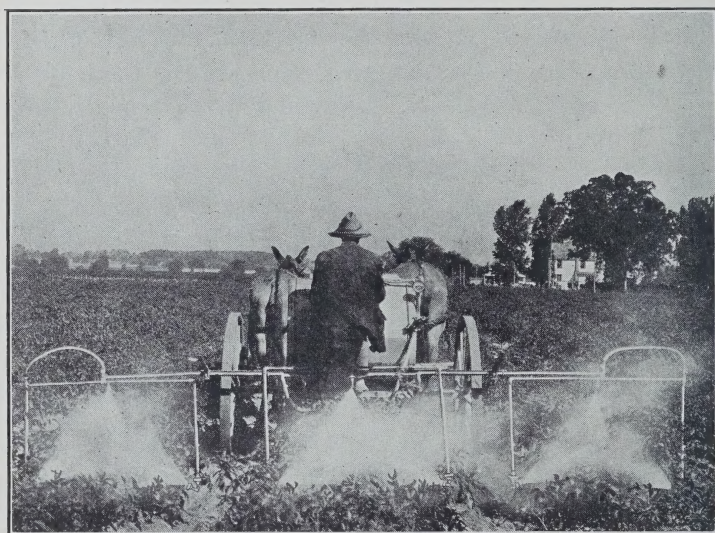


FIG. 29.—Traction Sprayer in Action. This Outfit will Spray Three Rows at a Time, Three Nozzles to the Row.

is useful, however, in vineyards and for a number of the vegetable crops, but its greatest use is in spraying potatoes.

The only good reasons for spraying any crop which is used for food is to produce a better and larger crop and to acquire a greater net profit. Only the most efficiently constructed traction sprayers will give these results, and because so few of the makes on the market meet the strict requirements now demanded in efficient work it is appropriate at this time to consider what factors make these requirements necessary.

Various investigators and observers have arrived independently

at the conclusion that spraying with a traction sprayer not properly equipped is a waste of time, money, and effort. When the pressure is only 75 to 100 pounds, and but one nozzle is used to the row, the pump capacity at its maximum is likely to be only 75 to 100 gallons per acre. Under such conditions the yield of potatoes is increased but little, if at all, and the expense of spraying may actually decrease the net profit per acre. The yield increases of twelve or fourteen years ago with potatoes were 20 to 25 bushels. The most approved practices to-day will not only double, but triple the former increases. Convincing proof that these statements are correct have accumulated in Virginia, Pennsylvania, Indiana, and in other places. Dean Watts states that during the season of 1921, 10,000 acres of potatoes were sprayed in Pennsylvania under the direction of the extension service of Pennsylvania State College.¹ The average increase in yield of potatoes in these demonstrations was about 75 bushels to the acre. Professor E. L. Nixon, who was in charge of this work, states that he will not approve the use of a traction sprayer for demonstrations in Pennsylvania which is not equipped with a triplex pump and a spray boom carrying three nozzles to each row and which will not maintain 200 pounds pressure with all nozzles in operation. The outfit should also deliver a minimum of 8 gallons a minute. At the time of the first application small disk openings may be used in the nozzles and only 100 gallons of spray mixture will be needed per acre. When the vines cover the ground 200 gallons will be required to the acre, larger disk openings will be necessary, and the pump has sufficient capacity to take care of this peak load. Not more than four traction outfits now on the market will meet these requirements. Four sprayers equipped with gasoline engines and designed especially for potato spraying have come to the attention of the writer as also meeting these requirements. Further discussion of the gas-engine outfits will be found elsewhere.

As growers come to realize more and more that spraying pays best when the requirements laid down here are most fully met, we shall find that only approved types of traction sprayers will be bought. At the present time, however, the approved types are in the minority in the potato regions.

Perhaps there was a time when the potato bug was the only serious pest on potatoes. One nozzle to the row might then

¹ Market Growers' Journal, May 15, 1922, p. 4.

represent fairly efficient spraying, but in many regions to-day the control of potato bugs is not the difficult problem. The potato aphid and the leaf hopper, also certain diseases, make thorough spraying necessary. The aphid and the leaf hopper feed almost entirely on the under surface of the leaves, making it important that every square inch of the upper and lower surfaces of the leaves should be covered with spray material. To meet these conditions three nozzles are now used to the row—one suspended above the plant to spray the upper surfaces of the leaves and two nozzles placed one on either side of the row at a 45-degree angle, driving the spray against the under surface of the leaves and toward the inner portions of the plant. The spray solution, when forced through the nozzles at 200 pounds pressure, surrounds the plant with a dense fog. Only this sort of spraying is now deemed satisfactory when a traction or power sprayer is used.

It is only fair to say here that a man who is an expert with a spray rod may do an excellent job of spraying with a barrel outfit at a pressure of 100 to 125 pounds, but in this case the man and not the mechanical equipment is the limiting factor. A man may move as slowly or as rapidly as may be necessary to do thorough work, but this would be an expensive, inefficient method of spraying a commercial planting of potatoes and authorities consider 6 acres as the least acreage which constitutes a highly profitable commercial unit.

A traction outfit delivers only a certain amount of spray solution to every 10 feet of plants. This amount is obviously the same regardless of the size of the plant because the operator cannot change the amount of spray delivered by speeding up his team nor by any other means than by changing the ratio of the gears or the size of disks in the nozzles. The gasoline power outfit is more flexible, for by changing the speed of the team one may increase or decrease the amount of solution per plant or per acre.

There are other factors which affect the efficiency of this work. Some farmers are very particular about planting their corn in straight rows by the check row method, but fail to apply the same care to potato planting. If the rows are not straight and the distance between rows varies, a great deal of trouble is bound to arise in spraying and this trouble increases as the plants become larger.

The tank capacity of traction sprayers is usually 100 gallons

although some are equipped with 50-gallon barrels and some have tanks exceeding 100 gallons in capacity.

Of course the right materials must be used at the proper strength, and they must be applied before the insect or disease is apparent. Spraying which is efficiently done one day will not be effective ten days¹ later because of the rapid growth of the plant.

Gasoline Power Sprayers. This type of outfit is used by the great majority of commercial growers of fruit and vegetables. High-powered outfits of this type are also used in the control of shade-tree pests.

In size these outfits range from the small single-cylinder pumps with a $1\frac{1}{2}$ -horsepower engine, a tank capacity of 100 gallons, and a discharge rate of $3\frac{1}{2}$ to 5 gallons per minute to the large four-cylinder pumps equipped with 300-gallon tanks and discharging 25 gallons a minute. In shade-tree work, even more powerful outfits are constructed, the size now coming into general use being a 35-horsepower outfit with a capacity of 50 gallons per minute and capable of generating a pressure at the pump of not less than 400 pounds.

Power outfits are made in various styles and for different purposes. Some outfits are constructed to spray low-growing truck crops as potatoes. Others are for vineyards requiring special nozzle equipment. The most common type is for orchard spraying.

The principal parts of each power sprayer are the engine, pump, pressure regulator, and tank. In general the outfit should be as light as is consistent with necessary strength and durability. It should be simple and compact in design and should have sufficient power to carry the load without too much of a strain on the pump and engine. The exact power requirements will vary a little with different outfits.

For the small power outfits a 2-horsepower engine is the minimum power which will prove satisfactory in the long run. Outfits are sold with less engine power, but in most instances they are not wholly satisfactory. It is a fairly safe rule for anyone considering the purchase of a power outfit to estimate his needs as accurately as possible and then add about 1 horsepower to the engine which he buys. When a power outfit is listed, for instance, with a discharge capacity of $9\frac{1}{2}$ gallons per minute the grower should not assume that this is the usual rate of discharge which he

¹ Penn. State College Ext. Circular 94, by E. L. Nixon.

may expect in the orchard. It is intended to show the maximum discharge capacity of the outfit when everything is in fine working

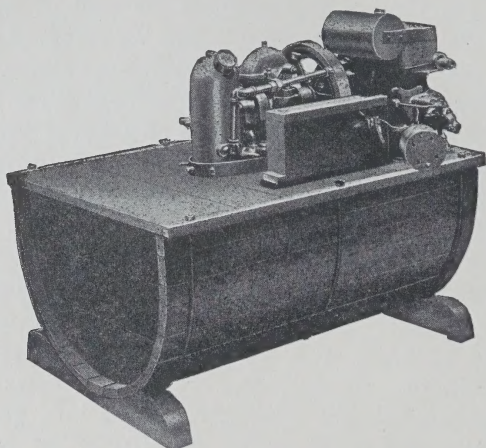


FIG. 30.—A Power Outfit which may be Mounted in Any Farm Wagon. The Engine Power may be Varied According to the Needs of the Buyer.

order, but not every sprayer will perform at the rate credited to it. In certain rare instances outfits while still new have been known to fall fully 20 per cent below their capacity rating.



FIG. 31.—This Outfit is Practically the Same as in Fig. 30, but the Two Large Wheels are Adjustable in Width, Light in Draft, and Adapted for Spraying Many Crops. Two-wheeled Outfits Allow for Very Short Turns.

Even with ordinary care an outfit rated at $9\frac{1}{2}$ gallons to the minute will probably, under usual working conditions, deliver

not to exceed 8 gallons. There are a number of things which account for this. In the first place no outfit holds up to its maximum very long. The wear on certain parts will account for a portion of the loss and the engine tends to idle down until it works more slowly. The slowing down of the engine reduces the number of strokes per minute for the pump and it is possible for an outfit to be discharging from 35 to 50 per cent under its proper rating. The grower may not discover this unless he checks on the number of pump strokes per minute at which the outfit is running.

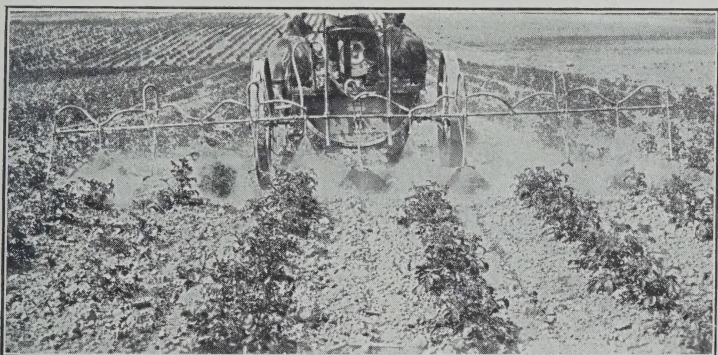


FIG. 32.—Combination Orchard, Vineyard, and Truck Sprayer Equipped with a Six-row Boom having Three Nozzles to the Row. The Outfit has a 6-H.P. Engine and can Readily Develop 200 Pounds Pressure with Eighteen Nozzles. The Six-row Boom may be Removed and a Special Boom Attached for Vineyard Spraying or Hose and Rod Attached for Orchard Spraying.

Other causes for the reduced rate of discharge might be a corroded screen at the intake to the pump which will reduce the flow of liquid, or worn valves preventing prompt reseating of the ball. Sediment, such as twigs or leaves or other materials, may also prevent the valves from seating properly and leaking plungers are an important source of trouble.

Some men purposely slow down the engine when they notice that a certain amount of spray is being returned to the spray tank through the overflow pipe. They feel that a return of so much material is a waste of engine power, but in some instances this is a mistake, for without a liberal supply of spray mixture in the overflow, it would not be possible to maintain pressure when

worn disk orifices materially increase the output of the nozzles, or pump troubles such as the faulty seating of a valve increase the burden on the remaining cylinder's adequate reserve. Another reason for permitting an overflow through the relief valve is to allow the engine to speed up and where this is necessary, the engine has been over-rated. If a machine is properly rated the overflow is not necessary.

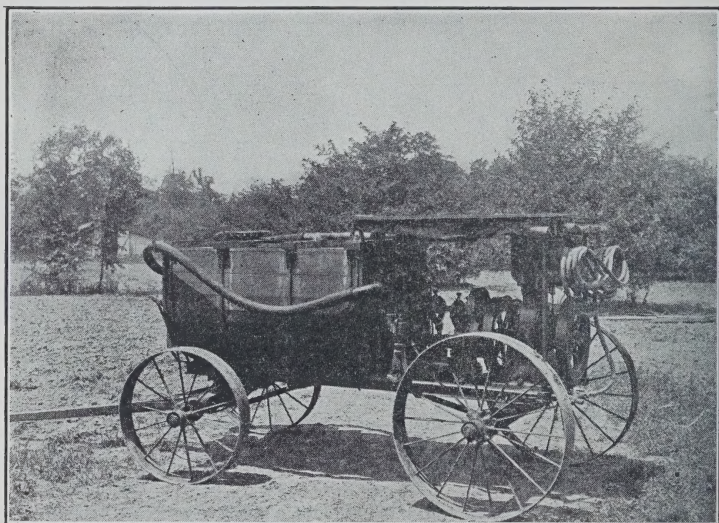


FIG. 33.—Triplex Power Sprayer. Another Type of Orchard Sprayer which is Equipped with a Tank Filler. The Pressure Regulator is at the Rear of the Tank on the Discharge Pipe. The Hose on This Outfit is Equipped with the Quick-change Coupling. Spray Material is Carried to Pump by under Tank Gravity Feed. It has a 4-H.P. Engine and a Maximum Discharge Capacity of $9\frac{1}{2}$ Gallons per Minute.

The best type of orchard sprayers have engines rating from 3 to 6 horsepower. The minimum rating is necessary for the proper operation of a spray gun.

The pumps on the majority of power sprayers are of the force-pump type, but there are a few rotary pumps on the market. The force-pump type may be driven by a belt, yoke, gear, or chain, but the gear and chain drives are most commonly used. Belt drives were formerly very popular, but belts wear out quickly and belt slippage results in the loss of power. Very few outfits

are now equipped with single-cylinder pumps, the duplex and triplex being the common kinds, with four-cylinder pumps now being manufactured for large capacity work. Duplex is merely a trade name for a two-cylinder pump and triplex outfits are equipped with three cylinders. The two named last not only give greater nozzle capacity, but also more uniform pressure than the single-cylinder outfit.



FIG. 34.—Duplex Power Sprayer. This Outfit is Built Very Low and is Capable of Making Short Turns. Note the Large Wheels which Support the Tank. Tank is Low, Easily Filled, and the Outfit Well Balanced for Hillside Orchards.

The advantages claimed for the rotary pumps are that they are remarkably simple in design, they consist of very few parts, and they have no valves to wear out or clog. With adequate engine power they are also guaranteed to maintain high pressure. Up to this time their usefulness has been confined to other liquids. Earlier attempts to use rotary pumps for spraying purposes showed lack of efficiency after a little use, due to wear of the gears which take the place of plungers in other pumps. The success of this comparatively new sprayer will be watched with interest as progress toward a substantial reduction in the number of working parts is a step in the right direction.

Pump plungers may be driven in various ways. Some manufacturers use a crankshaft drive and others use an eccentric or a walking beam. The last-named method can be used only on single- and two-cylinder pumps. Of these three the crankshaft drive is most popular.

Relief Valves and Pressure Regulators. Most of us do not fully appreciate the vital importance of a relief valve which works smoothly. In recent years manufacturers have perfected them to such a degree that they give very little trouble, but prior to 1911 fully 75 per cent of sprayer troubles were directly traceable to the inefficient valves then in use. At that time they were improperly called relief or safety valves. After they had been used a short time the spring would corrode or stick, causing the pressure to rise quickly 50 to 100 pounds. This would occur because the engine and pump worked constantly, while the flow of spray material was intermittent. With the nozzles shut off, the excess pressure would stall the engine, burst the hose or blow out connections, so the operator was forced to keep the nozzles open or stop the engine. If he risked a trial of the valve and it finally relieved the pressure it would unseat so completely as to expel about all of it.

A fundamental trouble with some of these valves was that not enough surface was exposed to the pressure, and the effect was a constriction similar to the limited flow of liquid through the neck of a bottle. Too much friction was also caused by a tight stuffing box, and this increased with the length of service. Another serious fault was that every bit of liquid not delivered to the nozzle was forced through the valve back into the tank under pressure, and when the nozzles were closed, the engine and pump were working under a pressure load about 50 pounds heavier than when they were open. More fuel was required for the engine and more strain was therefore placed on the pump when it was actually performing no service to the grower. The relief valve of the present day consists of a by-pass valve. The valve is kept seated by a spring at a certain definite tension, which in some cases may be regulated. When the pressure of the spray material against the valve is greater than the tension of the spring holding it, the valve is lifted and the spray material allowed to run to the tank. Relief valves are still used in great abundance for water pumps but are not suited for fruit and

garden power sprayers. Most types of relief valves are designed not to take care of large quantities of water or spray but only for a small overflow. The high velocity and pressure at which liquids pass through the valve cause the seat and valve to wear rapidly and function improperly.

At the present time the leading manufacturers have perfected

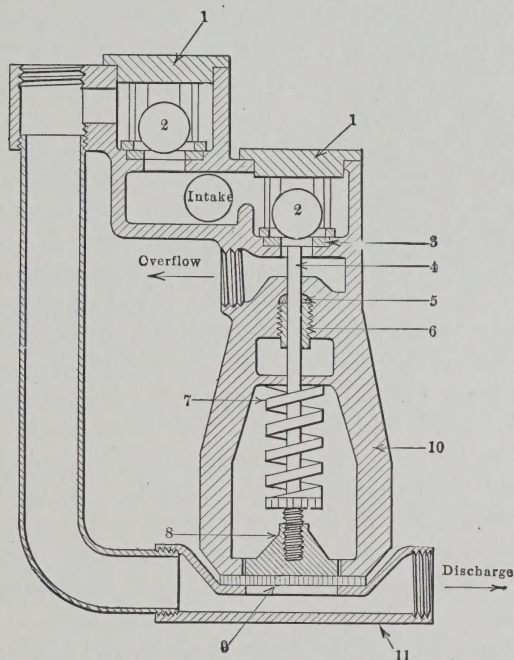


FIG. 35.—Sectional Drawing of Pressure Regulator.

- | | |
|------------------|--------------------|
| 1—Valve Cover | 6—Packing Nut |
| 2—Ball Valve | 7—Spring |
| 3—Valve Seat | 8—Diaphragm Piston |
| 4—Adjusting Stem | 9—Diaphragm |
| 5—Packing | 10—Frame |
| 11—Bottom | |

another type of valve in which these troubles are eliminated and they are more often called pressure regulators. This invention is quite different in its mechanical action from the relief valve, and a composite illustration is shown in Fig. 35. The pressure does not act directly on the valve, but on a diaphragm which lifts the valve by means of a plunger rod connecting them. By using a diaphragm the size may be varied so as to expose to the pressure as much surface as needed. One well-known regulator has about

16 square inches of exposed surface. Sudden increases in pressure are readily taken care of by means of this larger surface, making this type of valve very sensitive.

The diaphragm and the plate resting on it, also the piston shown in (8) Fig. 35, are held in position by the tension of a heavy spring. The more tension placed on this spring, the more pressure it will take on the diaphragm to raise it, and this may be increased or decreased by means of a special wrench. Unlike the stuffing box on the old relief valves, the one on the diaphragm piston causes very little friction.

When the pump is operated and the nozzles are open, the spray mixture is forced into the pressure regulator at a point between 1 and 3. It passes over the lower ball valve marked 2, lifts the upper valve marked 2, continues through the channel shown at the left of the diagram and out through the discharge pipe. When the nozzles are closed the pump continues to force liquid through the same channels until the pressure, which, for example, is set at 250 pounds, lifts the diaphragm, piston, and ball on the lower valve. This happens the instant the pressure exceeds 250 pounds and the liquid then flows directly from the pump through the valve at 3, passing out to the tank through a pipe attached at the point marked overflow. In the meantime the upper valve holds the pressure constant on the mixture in the channel beyond that point. When the nozzles are opened again, the lower valve seats quickly and the liquid again flows through the upper valve and around to the point of discharge.

The big advantage of the upper or check valve is that it holds the pressure in the waterway and takes the pressure load from the engine and pump when the nozzles are not operating. It takes only from 10 to 25 pounds to pump the mixture through the overflow pipe back into the tank, yet the check valve is holding 250 pounds pressure. In the course of a year this plan represents a considerable saving in fuel as well as wear and tear on the pump and engine. But what is far more important is that the operator rests secure in the feeling that he has a safe and dependable release valve.

The working principle of all pressure regulators used on power sprayers is practically the same, but there are minor differences in the way it has been applied. In some designs the check (upper valve in diagram) is sometimes placed below the diaphragm or

below the air chamber, making it more difficult to reach. In the event that sediment lodges under this valve it would then take considerable trouble to clean it out.

Some spraying machines are so constructed that the pump is connected directly to the air chamber, and in such cases it is not possible to install a pressure regulator like the one just described, unless the air chamber is discarded and a new one put on. Machines of this sort may be equipped with what may be called a diaphragm relief valve. It relieves pressure in the same way as the regulator described above, but it does not have a check valve, and, therefore, cannot take the load off the engine and pump when the nozzles are closed. In this respect it is similar to the old relief valves, but it differs in that the pressure acts on a large diaphragm instead of some small surface such as a portion of a $\frac{3}{4}$ -inch ball. This makes it more sensitive. It is satisfactory for small power sprayers or for machines not designed for the double-valve regulators.

To summarize the things which distinguish a relief valve from a pressure regulator we find:

1. A relief valve has one valve while a true pressure regulator has two.

2. The pressure acts directly on the bottom of the relief valve. On the pressure regulator it acts on a diaphragm, plate, and piston, unseating the valve.

3. The stuffing box on a relief valve has nearly the full amount of pressure working against it, thereby creating considerable friction. The other type of valve has practically none.

4. The relief valve while it starts to release at the pressure at which it is set, is unable to take care of the large volume of spray mixture unloaded upon it suddenly when the nozzles are closed. It works the pump and engine all the time, and hardest when the nozzles are closed. The regulator is accurate in releasing pressure, and works the pump and engine only when the nozzles are operating.

5. In the relief valve, whether the liquid is discharged or returns to the tank, it must pass through the valve under pressure. In the regulator the surplus liquid returns to the tank through the lower valve with no pressure load against it.

Spray Tanks. The tanks are usually made of wood bound by iron rods or bands. Metal tanks have been used to a limited

extent, but they are less often a part of the equipment to-day than formerly. Announcements come out periodically that metal tanks may be so treated as to prevent corrosion, but the fact remains that the wooden tank is more popular to-day although it must receive some attention to prevent drying out and in other instances the supporting rods must be loosened to prevent bursting or warping when the tank swells. Most tanks are built in the U shape. This allows practically all material to be withdrawn from the tank and it also allows for uniform agitation. In size they range from 100 to 400 gallons, depending on the nature of the work.

Spray mixture is carried from the tank to the pump by means of an overhead suction hose or by an under tank or gravity feed. Many manufacturers have changed from the former to the latter. With the under-tank feed no priming is needed to start the pump, as gravity carries the spray mixture to it. However, with the overhead suction there is at least one advantage, for when the grower wishes to leave spray material in the tank over night he may remove the overhead suction hose, insert it in a container of clean water and while the engine still runs may cleanse the pump and waterway thoroughly. The advantages of the two may be combined in the gravity feed type by having a valve in the supply line between the tank and the pump and providing for a means of attaching a short length of hose to the intake of the pump. This permits washing it out thoroughly without emptying the tank.

The frame or bedplate on which the engine, pump, and tank are mounted should preferably be made entirely of steel because of the heavy weight it must support and the great strain it sustains while the sprayer is in operation. Rigidity and strength in the frame is probably more important with the gear drive than with a chain or belt drive, for with the latter a slight deviation of the pump or engine from a true line will not make as much difference as with the gear drive.

The wheels should be made of steel when purchased as a part of the sprayer equipment, and, because of lighter draft, wheels of large diameter with wide rims are preferable. The extra cost of larger wheels is money well invested, for the draft on such outfits is a very important item on rough, hilly, or soft ground. The range in wheel diameters on the largest orchard outfits is from

28 inches for the front wheels and 32 inches for rear to 48 inches for front and 54 for rear on special equipment. On the smaller wheels a rim 4 inches wide is generally used, while the other extreme requires a 5- or 6-inch tire. Even this width is not sufficient in some instances and auxiliary wooden rims or flanges are attached when sprayers must be used in muddy ground. These auxiliaries are described under special equipment in the chapter on Accessories. The flange idea has also been adopted by some manufacturers on motor trucks when they must be used for spraying purposes on soft ground.

Orchard sprayers should be built low for convenience in moving about the orchard and to keep the center of gravity as low as possible on hilly ground. A rocking bolster on the axle will keep the frame level even though one wheel gets into a hole while the others remain on high ground. The outfit should also be designed so that the turns may readily be made.

The rate of discharge and the pressure developed for a power sprayer equipped with a force pump depends upon the number of cylinders, the diameter of the cylinder, the length of the stroke, and the speed at which the pump is operated. The following table has been worked out by one of the leading manufacturers of spray machinery.

Number of Cylinders	Horse Power	Diameter of Cylinder, In.	Length of Stroke, In.	R.P.M.	Pressure, Lb.	Capacity per Minute, Gal.
One.....	1½ or 2	2¾	4½	40-50	275	4¾
One.....	2	3	4½	40-50	275	5½
Two.....	2 or 3	2½	2¾	40-50	275	5½
Two.....	3	2¾	2¾	40-50	275	7
Two.....	3	3	2¾	40-50	275	7½
Three....	3 or 4	2½	2¾	40-50	275	8
Three....	4 or 6	2¾	2¾	40-55	300	9½
Three....	6	3	2¾	40-50	250	12
Three....	6 or 15	3	4	40-50	300	14
Three....	15	3¼	4	40-50	300-400	16-20
Three....	15	3½	4	40-50	300	25

Large-capacity Orchard Sprayers. The invention of spray guns has developed a tendency with some growers to favor outfits

maintaining 250 to 300 pounds pressure and discharging comparatively large volumes of liquid.

One firm meets this tendency by increasing the diameter of their plungers and the length of stroke in a triplex pump, equipping the outfit with a 15-horsepower engine. The maximum nozzle capacity for outfits of this size is two guns equipped with large disk openings, three guns with medium disks or their equivalent in small capacity nozzles.

Sprayers of this type are being used not only in the orchard, but to a limited extent in spraying parks, private grounds, street and forest trees. Their usefulness in this direction is limited, as they do not have sufficient capacity for spraying a large territory or tall, mature trees, without considerable climbing, which would materially increase spraying costs.

Two other firms have designed a four-cylinder pump which is operated by a 10-horsepower, four-cylinder engine. Both outfits can readily discharge 20 gallons of spray mixture per minute and at maximum working capacity they will deliver several additional gallons. In commercial orchards where a large output for each man and machine are of great importance these outfits are well liked, yet the great bulk of the orchard spraying is still being done with outfits having a capacity proportionate to the power of a 3- or a 4-horsepower engine. Those who are in a position to know, because of their contact with growers, believe that the field for sprayers of this type is limited and that there may be a reaction in favor of less expensive outfits of smaller capacity. Perhaps the future of these outfits depends in a measure on the future popularity of the gun in orchard spraying, but their greater output with practically no increase in team labor is a point in their favor. The number of men required to do a certain amount of work is also reduced.

Shade-tree Sprayers. This special type of sprayer has come into use in the attempt to control brown-tailed moths and especially the gipsy moth in the New England states. Several thousand tons of arsenate of lead and about 1000 high-duty sprayers are used in New England alone. Thousands of acres of park and orchard trees and woodland, also 30,000 miles of street trees, are sprayed with these outfits.

The present efficient spray outfits for this special work are the result of much study and many changes and improvements. At

the present time equipment is available which varies in power, capacity, and efficiency, but is designed to meet adequately the varying needs of towns, parks, and cities. Two sizes are available in horse-drawn outfits and several sizes in motor-truck sprayers.

Description of Horse-drawn Outfit. A general description which will fit either size would include the following points:¹

Caravan running gear, U-shaped tank of 200- or 400-gallon capacity, phosphor-bronze pump with engine power either about 16 or 35 horsepower. The running gear is of best oak stock and

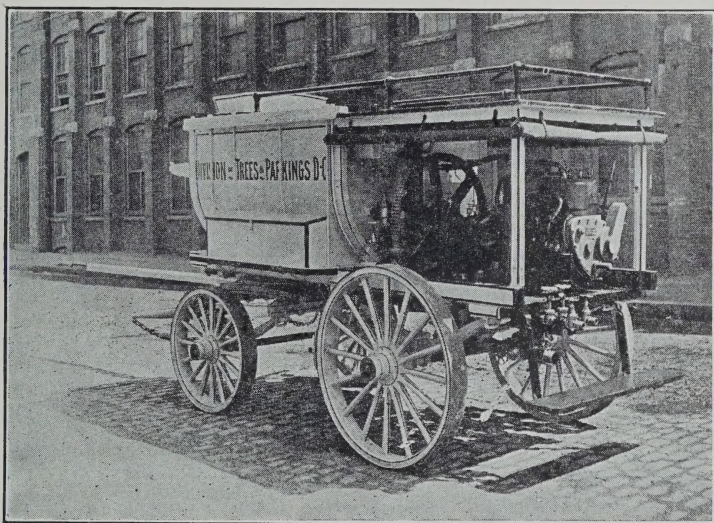


FIG. 36.—View of Shade-tree Spray Outfit. Has a 36-H.P. Engine and Will Discharge 50 Gallons at 600 Pounds Pressure.

high-grade steel. The wheels have wide tires, the front wheels cut under, the wagon is equipped with springs all around, and is built for a two-horse hitch. The tank and cab over the pump and engine have a solid roof on which supplies may be carried.

The pump is of the triplex type with plungers, cylinders, valves, and valve chambers made of high-grade phosphor-bronze with a tensile strength of 50,000 pounds per square inch. This material allows for the design of a pump which is much lighter than one made of cast iron which rarely has a tensile strength of

¹ U. S. D. A. Bul. 480, Solid Stream Spraying against the Gipsy Moth, by L. H. Worthley.

more than 16,500 pounds per square inch. The cylinders and displacement chambers are cylindrical in design so as to offer no flat surfaces to pressures. Greater strength is thus secured with the same amount of metal. The valves and waterways are extra large to permit speed while filling. The crank is drop-forged and has a much higher elastic limit than a cast-iron crank. The pump is attached to the engine by a durable clutch with a gear and pinion. The pump is equipped with two automatic safety release valves which may be set at varying pressures. By thus having two valves it is possible to use a variation in pressure in field work without running the engine at an excessive rate of speed. These valves are properly set and should not be adjusted in the field. It is very important that agitation should be constant and thorough. The type of agitator used is described earlier in this chapter under the discussion of agitators.

The smaller type of horse-drawn sprayer delivers 12 gallons per minute at 300 pounds pump pressure while the larger type is manufactured in two styles, the former giving 50 gallons per minute at 400 pounds pressure and the latter delivering the same amount at 600 pounds pressure. These outfits are used with a solid-stream Worthley nozzle and have sufficient capacity to be useful in the smaller towns and parks.

Motor-truck Sprayers. Spraying work in the gipsy-moth area developed to such an extent that as early as 1910 a motor-truck sprayer was built for use in the state of Massachusetts.¹ Numerous changes and improvements have been made since that time until to-day trucks varying in tonnage from 2½ to 5 tons are equipped for large spraying operations. All of these types have a capacity of 50 gallons per minute, but the more powerful engine generates higher pressures at the pump. The smallest truck outfit will develop 600 pounds, while the largest in general use develops 1000 pounds pressure.

The three-ton truck will accomplish more work in a single season than four horse-drawn shade-tree sprayers and can be operated more economically on account of saving time on the road and reducing the number of men needed. They are particularly useful where long lines of hose are needed and where water must be hauled long distances. Shade-tree spray outfits may be mounted

¹ U. S. D. A. Bul. 480, Solid Stream Spraying against the Gipsy Moth, by L. H. Worthley.

on any truck where the transmission is amidship. This provides for installing an adequate drive on the main line shaft, as the average transmission take-off does not allow for transmitting continuously a sufficient amount of power.

The truck engine should be of oversize as the truck not only must propel itself, but also must maintain high pressure for spraying. A special transfer arrangement to the pump makes it possible to spray while traveling or standing, and the outfit is equipped with three speeds forward and one reverse. Controls

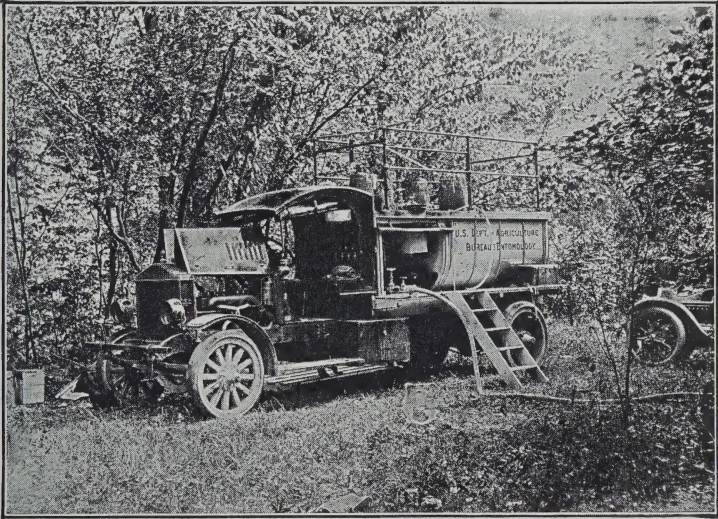


FIG. 37.—Large Power Sprayer for Shade-tree Spraying. Has a Capacity of 50 Gallons per Minute at 1000 Pounds Pressure. Is Equipped with a Poison Mixer. Note the Size of the Hose.

for the truck as well as the spraying attachment are accessible from the driver's seat. The pump is practically the same in design as on the horse-drawn outfits except that it is reinforced to stand higher pressures.

A five-ton truck with a worm drive and a pump of greater capacity is now in use for the most difficult type of spraying work.

When the sprayer-truck combination is not needed the pump and tank attachment can be removed and a different body attached, suited to general purposes in transportation of supplies or for other work.

CHAPTER IV

SPRAYING ACCESSORIES

It is quite possible to have an excellent spray machine, yet the accessories may be inadequate and unsatisfactory. This lowers the efficiency of the crew and the machine. The sprayer, like the automobile, requires accessories which are not included in the original purchase, and in spraying they are more likely to be essential.

SPRAY NOZZLES

Ever since the subject of spraying has engaged the attention of food producers, men have been seeking ways of applying spray mixtures more efficiently. Perhaps no one piece of equipment has received so much attention as the nozzle. Some of its predecessors were the whisk broom, the syringe, the sprinkling can, and the solid stream garden nozzle. Then in 1858 a nozzle giving a fan-shaped spray was designed, and 1884 marked the christening of the Vermorel. This nozzle consisted of a long narrow chamber in which the liquid takes on a whirling motion by means of an angled entrance, or through the medium of a spiral device surrounding a central spindle. This spindle is extended to clean the nozzle orifice through which the liquid is forced, and when not thus used, the spindle is held in position by means of a spiral spring. The spray produced by a Vermorel is a fine, cone-shaped mist.

The basic principles of this invention were modified in 1906 into the disk type, which is the most useful small-capacity nozzle of the present day. It consists of two disks separated by a rubber gasket, grouped within a metal base, and all parts held in place by a cap. The inner or supply disk has two or more holes which are bored at an angle, thus imparting a whirling motion to the liquid. The outer disk is of thin steel, having a small hole in the center through which the liquid leaves the nozzle in a mist like spray of hollow cone shape.

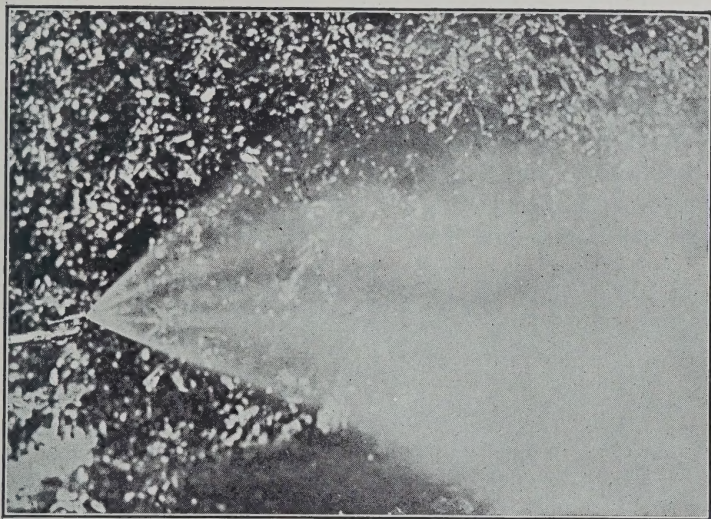


FIG. 38. Vermorel Nozzle. Throws a Very Fine Spray. Distribution Even. Disgorger Likely to Catch in Branches.

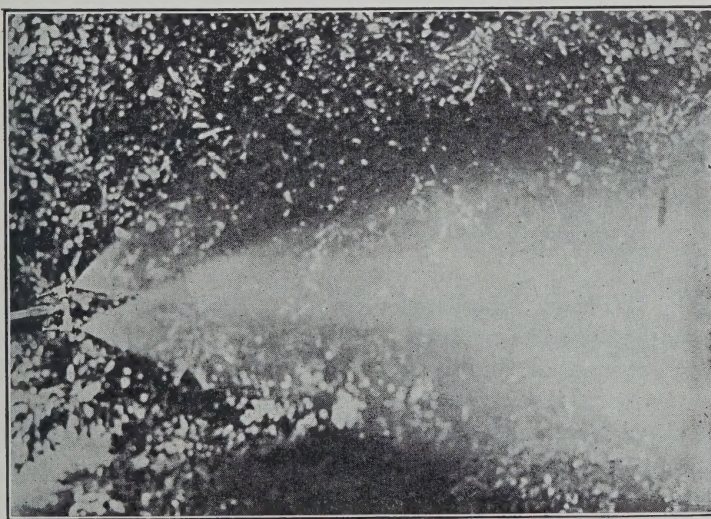


FIG. 39.—Double Vermorel Nozzle. Throws a Fair Amount of Very Fine Spray. Distribution More Even than Disk Nozzles. It is Not Convenient to Handle due to Weight and Ease of Catching in Branches. Three and Four Vermorels are Sometimes Used in a Cluster by Growers Who Prefer Its Mist-like Spray. Not Used as Much as Formerly.

Another factor in the evolution of types was the Bordeaux,¹ a modification of the solid stream nozzle, originating in 1878. Discharge of spray from this type was provided by boring a hole through the stem of a stopcock which formed the centerpiece of the nozzle. The spray might be discharged in a solid stream or, by adjusting the stopcock, the outlet orifice might direct the stream against a projecting portion of the nozzle, thus breaking it up into a fan-shaped spray. The Bordeaux, the disk, and the solid stream shade-tree design represent the three main types of nozzles in use to-day.

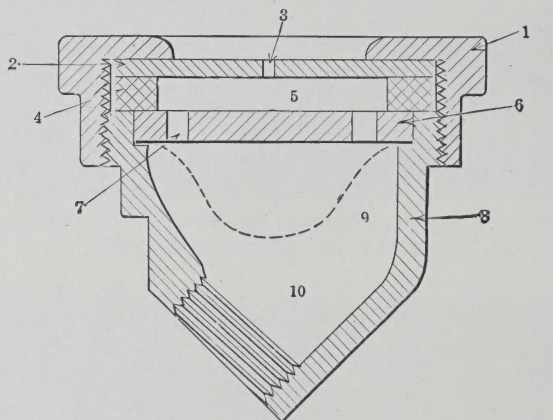


FIG. 40.—Sectional Drawing of an Angle Disk Nozzle.

- | | |
|--------------------|-----------------------|
| 1—Cap | 6—Directing Disk |
| 2—Disk | 7—Oblique Supply Hole |
| 3—Orifice | 8—Base |
| 4—Gasket or Washer | 9—Strainer |
| 5—Eddy Chamber | 10—Reservoir |

The Bordeaux type supplemented the range of usefulness of nozzles because the material was projected to greater distances beyond the outlet, and for a number of years a coarse driving calyx spray for the codling moth was considered necessary. When numerous comparative tests with fine and coarse nozzles for efficiency in control of codling moth showed no decided advantage in favor of either type, the Bordeaux nozzle lost much of its popularity because its use meant a waste of spray mixture and an increase of 50 per cent in the cost of materials. The added distance gained by the Bordeaux type has been increased and the type

¹ West Virginia Bulletin 169, p. 11.

of spray improved upon in more recently perfected large-capacity disk nozzles. Such nozzles include the Friend Calyx and the Hayes Jumbo. But even this increase in the discharge capacity of nozzles and in the efficiency of man labor served only as a connecting link in the evolution of nozzles designed to meet these needs to a much greater degree.

Scarcity of labor during the World War greatly accentuated the importance of individual efficiency and in spraying work the

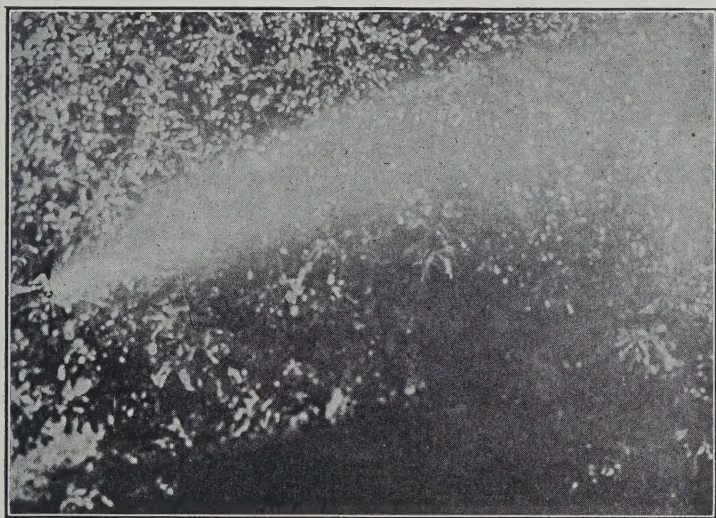


FIG. 41.—Bordeaux Nozzle. Gives a Coarse, Driving Spray. Its Distribution is Uneven. The Caswell Nozzle is a Bordeaux of a More Improved Type.

problem was met in 1916 in the development of the spray gun. This invention was also an effort to meet the competitive efficiency of the power dusting outfit.

For these reasons no piece of equipment produced since the advent of the power sprayer has created such general interest and has been so quickly accepted as the gun. Its value as compared with other nozzles is considered in detail later.

Deviating from the chronological order of nozzle evolution we find the one with the greatest capacity of all, perfected by L. H. Worthley of the U. S. Department of Agriculture in 1910 for shade-tree spraying. This invention marked a long forward step

in the efficiency of this work. Trees from 25 to 100 feet tall are now sprayed from the ground, and the nozzle requirements, which vary with the height of trees and other factors are met by four removable jets, each having an orifice of a different diameter. The smallest jet or tip has a discharge capacity of 6 gallons of spray mixture per minute while the largest delivers 45 gallons. Obviously the greater the capacity of the jet, the taller the tree that may be effectively sprayed, provided the machine behind it has sufficient capacity.

Classification of Nozzles. Three principles have been used in the construction of practically all nozzles now on the market, and these principles form a basis for the natural division of nozzles into three groups.

1. Spray nozzles in which the stream, having passed the outlet, is broken into a fan-shaped spray by devices which obstruct its direct forward passage. The Bordeaux nozzle in its various forms represents this group.

2. Spray nozzles in which a high-pressure rotary motion is given to the liquid which produces a cone-shaped spray as it leaves the orifice.

The various forms of the small disk nozzle, also its forerunner, the Vermorel, as well as the spray gun belong here, making it the most important of the three groups in range of usefulness.

3. Spray nozzles in which the stream is affected only by the modifying action of the margins of the outlet, and by the resistance of the air, which breaks the stream into a spray before it settles upon the plant.

The Worthley solid stream nozzle typifies this group.

Materials Used in Nozzles. The greater portion of any spray nozzle is made of brass or bronze because of the comparative immunity of these alloys to the corrosive action of spray materials. Disk nozzles have a disk made of steel and a centrally located outlet. Due to wear caused by expelling the spray under pressure, this outlet becomes larger and larger. Worn disks waste spray material and may overload the pumps or the source of power behind them. Moreover, the spray may be so coarse that a well distributed, misty deposit on the plant may be an impossible accomplishment for the operator. Disks should be replaced as often as they show wear, and an extra supply should always be kept on hand.

The actual weight of a nozzle is multiplied many times at the

remote end of a 10-foot bamboo rod, especially when two or more are used in a cluster, and manufacturers, in their desire to please the grower, have constructed a lighter aluminum nozzle with a removable porcelain eddy chamber. But aluminum threaded on aluminum, sticks, and is too light to withstand the rough treatment made necessary by applying a Stilson wrench to loosen the cap on the nozzle. Aluminum threaded on bronze or brass will not stick, and this compromise will provide a nozzle intermediate in weight. This scheme has been tried most recently on spray guns.

Other things being equal, the nozzle with the fewest loose or removable parts is the most useful, as there is less likelihood of losing parts when the nozzle must be opened and cleaned in the field. And the deservedly popular nozzles are the ones which wear. Durability should not be sacrificed for the sake of lightness. The lightest ones on the market will weigh about $1\frac{1}{4}$ ounces, while the heavier ones ordinarily used will weigh between 3 and 4 ounces.

Perhaps most growers would not guess that the rod and nozzle represent heavier equipment than the spray gun, but the heaviest tested¹ weighed 3 pounds and 14 ounces, while the rod alone weighed 4 pounds and 2 ounces. Because small nozzles are attached to the rod at an angle, there is a certain amount of back pressure in spraying which will average around 3 pounds on power outfits. When the operator must work against the leverage of this back pressure at the other end of a 10-foot rod the work becomes quite tiring in the course of a day.

Nozzle Tests. Any accessory so important as the nozzle is sure to invite investigation and many different state experiment stations have considered it. Such factors as the amount of liquid discharged per minute at various pressures, the character and distribution of the spray, and the angle of discharge have received attention.

Apparatus. Special apparatus is needed for this work including a sprayograph and a stand to provide uniform height and distance for nozzle tests. The desired pressures may be most readily obtained by using a power sprayer.

Since the sprayograph may prove useful in laboratory and thesis work, and because it is difficult to find a description and work-

¹ Thesis by I. H. Swaim, Dept. of Hort., Purdue Univ., 1922.

ing plan for one, it may not be out of place to offer that information elsewhere in this manual. (See Exercise No. 72.)

Results of Tests. In work carried on at Purdue¹ and West Virginia² universities twenty-six manufacturers donated over sixty designs of small-capacity nozzles. The great majority were of the modern disk design, and most of the remainder were about

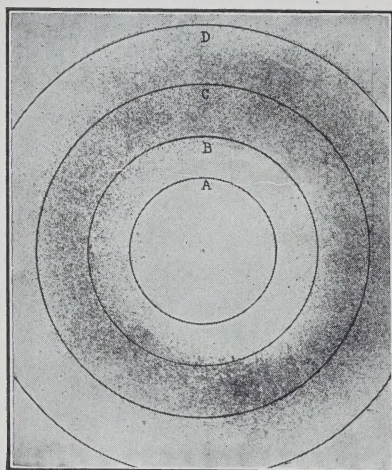


FIG. 42.—Showing Typical Distribution of Spray from a Disk Nozzle of Ordinary Capacity.

equally divided between Vermorel and Bordeaux types. A few solid stream nozzles of varying capacity were also included. Some of the facts which these and other investigations have brought out are as follows:

1. Disk nozzles in many designs tend to throw a spray in the form of a hollow cone having a heavy ring of spray with practically no material in the central area. Bordeaux nozzles give a more uniform distribution and Vermorel the best of all.

2. A fault common to many hollow cone disk nozzles

is their tendency to throw most of the spray in one-half of the circle.

3. The smaller the angle of the supply holes leading into the eddy chamber, the wider is the angle of discharge and the smaller the drops of spray.

4. When the depth of the eddy chamber is increased the size of the spray particles and the rate of discharge increases, but the angle of discharge and the width of the ring of spray decreases.

5. A central supply hole in the eddy chamber makes the hollow

¹ Thesis by J. R. Tranter and F. R. Walker, Dept of Hort., Purdue University, 1914.

² Crane, H. L., A Study of Spray Nozzles, West Virginia Bulletin 169, 1919.

cone of spray a solid one, narrows the angle of discharge, and increases the size of the particles. A thick disk will give the same results and also decreases the discharge capacity of the nozzle.

6. When the size of the outlet orifice is increased, the ring of spray is widened and the angle of discharge and the amount of spray delivered is increased.

Increasing the pressure produces the same results and also breaks the spray into finer particles.

7. The amount of material delivered varies with the size of the disk opening and the pressure. Doubling the pressure does not double the amount of material delivered by the nozzle. The ratio of increase is 1 to 1.4.

8. Doubling the diameter of the outlet orifice increases the amount of material delivered about 3.5 times.

9. Tripling the diameter of hose gives no increase whatever in the discharge capacity of a nozzle having a disk opening of $\frac{7}{64}$ of an inch. Hose $\frac{1}{4}$ inch in diameter is large enough for this type as it will average just as well in discharge capacity at the nozzle as hose $\frac{3}{4}$ of an inch in diameter.

10. Hose varying in length up to 40 feet had no effect on the discharge capacity of the nozzle.

Choosing a Nozzle. There is no one nozzle which will fully meet all requirements. Operators are more particular and more diverse in their selection of a nozzle than any other farm accessory. To favor one type over all others in the presence of a group of successful growers would merely give rise to an argument. But there are certain observations which may be made for each of the various types.

As previously noted, the standard Bordeaux nozzles are not used as much as formerly. An improvement on the standard type known as the triple Caswell is known to do good work. As the name implies, it has three nozzle orifices. The spray mixture passes beyond the orifices and meets a steel plate having a beveled edge. This obstruction produces a continuous fan-shaped spray from the three openings, delivered at a 45-degree angle.

The Caswell is equipped with large orifices when Bordeaux mixture is used in order to reduce clogging. The distribution of spray is unusually wide and the theoretical capacity with Bordeaux adjustment is 2736 gallons in a 10-hour day. These figures are merely theoretical, since this amount can be discharged only when

the nozzle is constantly in operation. In actual practice nozzles will be shut off frequently while the outfit is moved about, and also when the tank is being refilled. The Caswell also has nozzle adjustments to be used when lime sulphur is applied. Since the orifices are smaller, only 2058 gallons of mixture are discharged in a 10-hour day. This nozzle may be attached to a bamboo rod. Its advantages are that it has great capacity—more than a gun with a medium disk. It delivers spray at an angle, thus spraying

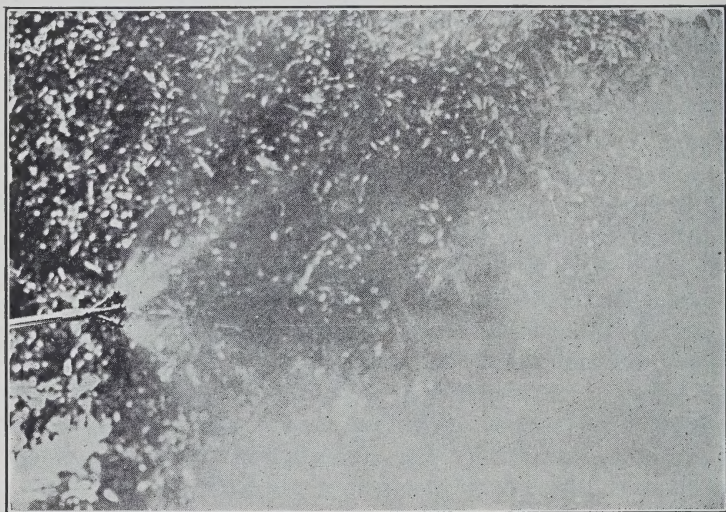


FIG. 43.—Triple Caswell Nozzle. Throws a Fine Fan-shaped Spray. Distribution is Even. Capacity Greater than Spray Guns Equipped with Medium-sized Disk Openings. A Bordeaux Type.

under surfaces easily and well. On a 10-foot rod it will spray to a height equal to a gun. The main disadvantages are that the nozzles must be adjusted carefully to produce a spray of continuous fan shape—and they clog easily. Special care should be exercised to exclude from the tank and waterways all material likely to clog this nozzle.

Vermorel Nozzles. An outstanding feature of this type is the remarkable evenness with which the spray mixture is distributed. This is shown in Figs. 38 and 39. The standard designs are of small capacity and in orchard work, two, three, or even four nozzles may need to be clustered together to make the work of the operator

efficient. Such clusters make an exceptionally heavy nozzle likely to catch on the twigs and branches of the tree. Although the Vermorel is still used to a limited extent, its general use has largely been discontinued except in instances where the finest mist is desired. Some growers claim that they can obtain a higher percentage of perfect fruit by using it. In recent years its greatest use has been on hand sprayers or potato sprayers, but even here it is now being superseded by disk nozzles equipped with extra small disks.

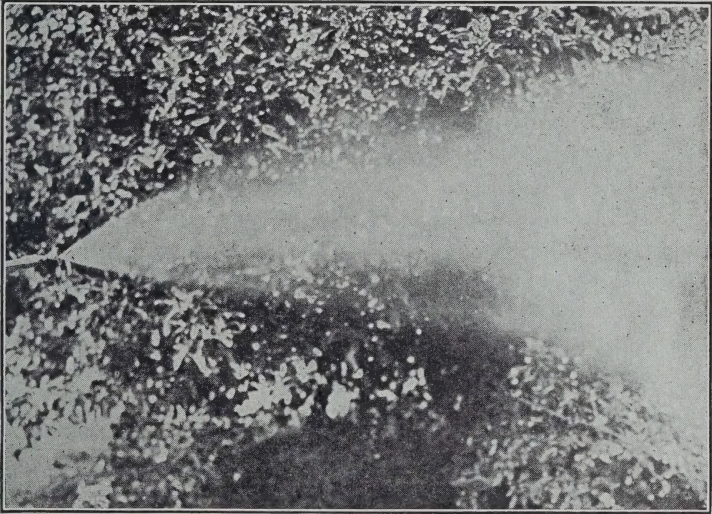


FIG. 44.—Angle Disk Nozzle. Throws a Fine Spray. Easy to Handle because It is Light and Compact with No Parts to Catch on the Branches.

Disk Nozzles. This type is fundamentally a Vermorel, having certain improvements, such as greater compactness, greater capacity, and wider distribution. It is easily the most useful and popular nozzle on the market. It may be equipped with disks of varying size selected according to the work to be accomplished. By attaching a Y to the spray rod each man may be operating two nozzles, thus doubling his output and making it fully equal to that of a spray gun with a medium-sized disk. The Y's may be constructed with a 45-degree angle when straight nozzles should be attached. Straight Y's are also available on which angled nozzles may be fitted. The selection of these accessories depends

on individual preferences. Other uses for Y's include attachment to the discharge pipe on a spray outfit so that two leads of hose may be used instead of a single lead.

Disk nozzles larger than standard size are to be found on the market. Their purpose is to increase the output per nozzle and the capacity is claimed to be the same as the gun. Two standard disk nozzles on a Y will increase the output about 900 gallons over one used alone so this combination is generally preferred to the larger

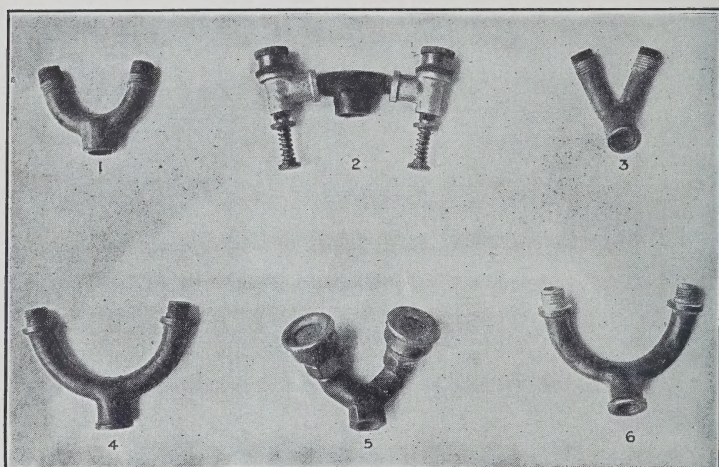


FIG. 45.—Nozzle Y's

- 1—Narrow Straight Y
- 2—Double Vermorel Nozzle
- 3—Narrow Angle Nozzle Y

- 4—Wide Straight Y
- 5—Narrow Angle Y with Two Straight Disk Nozzles
- 6—Wide Angle Y

than standard nozzle, because they give gun capacity, a finer spray, and better distribution.

SPRAY GUNS

All spray guns shown in Fig. 13 are essentially disk nozzles. They have merely been designed to discharge approximately twice as much spray mixture per minute with small disks as is delivered by the standard disk pattern. Guns vary in length from 18 to 34 inches. Because of this short barrel, spray may be directed over a wide tree area by a very slight motion of the wrist. In this respect the gun is easier to handle than a spray rod. On the other hand, a short barrel is a disadvantage to the operator

on windy days because it is almost impossible to keep out of the drifting spray which is whipped about by gusts of wind.

In operation, guns have three spraying adjustments—a fine spray for close range, a coarser discharge for medium distance, and a still coarser spray for long-range work. By utilizing these adjustments, steps may be saved and extra motions eliminated for the operator, but the danger lies in too great economy of effort on his part when the gun is used. This tendency decreases the efficiency of the spraying and gives rise to unfavorable criticism of the gun.

No nozzle in general use has warmer advocates nor more critical opponents. Probably it is safe to assert that the average man will get better control of pests with a rod and nozzle. It may also be true that when the highest possible percentage of perfect fruit is desired it will be obtained more often with a rod. Nevertheless, in experimental and demonstration work, where the gun has been used, spraying for such persistent diseases as scab and blotch has resulted in over 90 per cent perfect fruit.

The gun is an accessory which requires special and careful study if it is to be used successfully, and without attempting any defense of this nozzle some of the reasons for failure to operate the gun successfully may be considered here. The

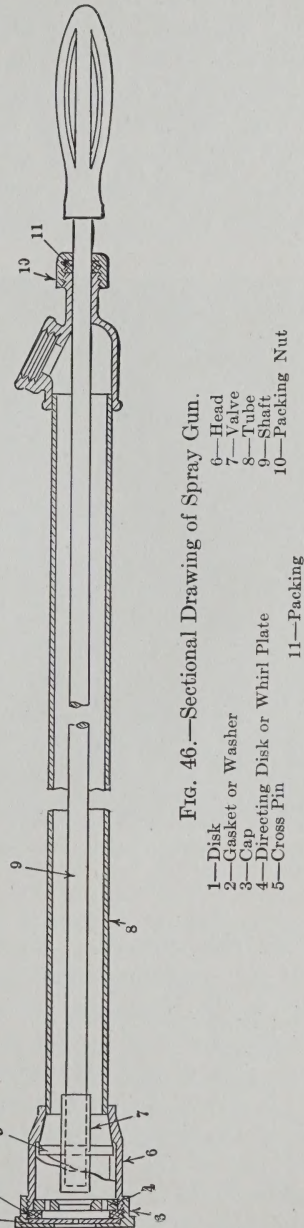


FIG. 46.—Sectional Drawing of Spray Gun.

- | | |
|---------------------------------|----------------|
| 1—Disk | 6—Head |
| 2—Gasket or Washer | 7—Valve |
| 3—Cap | 8—Tube |
| 4—Directing Disk or Whirl Plate | 9—Shaft |
| 5—Cross Pin | 10—Packing Nut |
| | 11—Packing |

two most important factors are the man and his knowledge of the gun. The man must be adaptable, for he cannot use a gun in the same way as the rod. The three adjustments of the gun must be used frequently for the objective is far away one moment and close at hand the next. Some operators are guilty of using the long-range adjustment most of the time, when in the majority of instances it should be used least of all. Long-range spraying drenches the tree and wastes material, yet the tree may not be

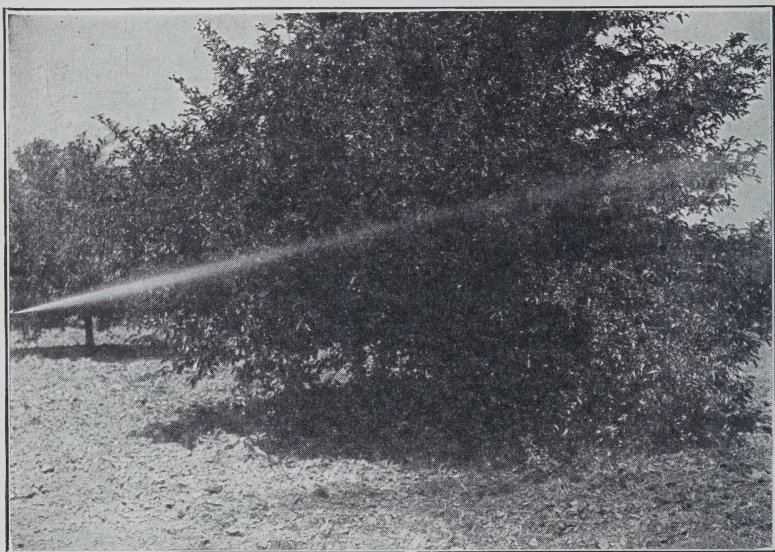


FIG. 47.—Spray Gun in Operation. Illustrating a Long Spray for Distant Spraying.

thoroughly sprayed. Drenching not only may cause spray injury, but does not represent good spraying. A misty film coating on the leaf is the ideal type of spray. When the amount of mixture applied varies with each succeeding spray it is a pretty certain indication of variable work and ineffective pest control.

It should be remembered also that the gun has no angle to direct the spray toward the under side of the limbs and the under surfaces of the leaves. If the tree is not headed too low this tendency to neglect the lower surfaces may be overcome by beginning to spray large trees from a position close to the main

trunk, spraying the inner portions of the tree, the lower sides of the branches, and following systematically back and forth along the limbs all the way around the tree. Finally, before leaving this position, the upper and inner portions of the tree may be sprayed with the coarse adjustment and not until this is done will it be desirable to spray the outer portions of the tree. The tendency with beginners and with some others is to attempt to spray large trees entirely from a position beyond the spread of the branches. Unless the tree is extremely high in head, it is almost impossible

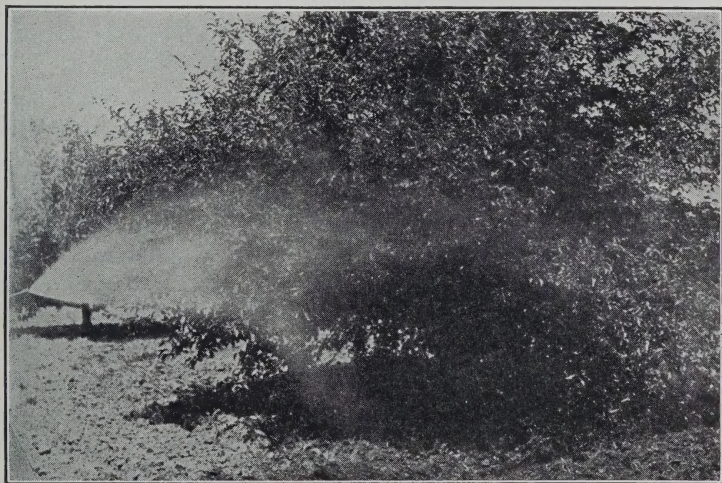


FIG. 48.—Spray Gun in Operation. Adjusted to Throw a Wide Cone-shaped Spray for Close Spraying.

to do a thorough job by this method. And after a tree has been superficially sprayed from the outside the operator is not likely to get under the dripping branches to put on the necessary finishing touches.

Many have entertained the mistaken notion that the gun will spray all portions of a tree, even large trees, when operated from the ground. This is too much to expect of the gun for in comparative tests carried on in Oregon¹ it was found that guns and rods were equally effective up to a height of 22 feet in the tree. Above that height neither one was effective, so we should expect no more

¹ Oregon Station Bul. 171, Spray Gun Versus Rod and Dust in Pest Control.

from the gun than from the rod on that score. The fact that a stream of spray may be projected from a gun to a height of 26 or 28 feet does not mean that effective spraying can be done at that height. In a horizontal direction guns will throw spray mixture several feet farther than vertically—probably an advantage in spraying the lower portions of large trees.

Growers who have been successful with the gun frequently use it on one lead of hose and a rod and cluster nozzle on the other. Where the trees are low-headed the rod will be used from the ground and the gun in a tower. Where the trees are high-headed sometimes the process is reversed. Where trees are mature a spraying tower should always be furnished with the outfit.

It pays to give careful attention to the size of the disk opening used. Because of the high pressure required with the gun, the size of the orifice may be quickly worn to a larger diameter. In some instances the disk is too large in the first place for the outfit on which it is used. In both cases the rate of discharge may represent an overload for both engine and pump. Guns may be provided with disks of seven different sizes, varying from unusually small to the extremely large size. Assuming that the spray outfit is operated at 250-pounds pressure the output of a gun using various disk openings is as follows:

Size of Disk Opening	Amount of Liquid Passing through Disk Opening in One Minute
$\frac{3}{32}$ in.....	5 gals.
$\frac{7}{64}$ in.....	6 gals.
$\frac{1}{8}$ in.....	9 gals.
$\frac{9}{64}$ in.....	12 gals.
$\frac{3}{16}$ in.....	20 gals.

A disk opening $\frac{1}{16}$ of an inch in diameter is also furnished for small trees and for oil spraying. Another disk opening $\frac{7}{32}$ of an inch in diameter is provided for very large capacity outfits to be used on the largest trees. The sizes most frequently used in orchard work should be the $\frac{3}{32}$ -inch or $\frac{7}{64}$ -inch disks.

Perhaps a practice which too often condemns the gun is its use on an outfit which has insufficient power to operate it. If the gun capacity of disk openings just considered above is compared with the discharge capacity of the sprayer the mistake of over-

loading the engine and shortening the life of the outfit may be avoided. Most duplex sprayers do not have sufficient capacity to operate a gun day after day in the field, although they may appear to do so when the outfit is new and under demonstration. Furthermore, none of the triplex outfits with a 3- to 4-horsepower engine, have sufficient capacity to operate two guns properly. Various experiments which have been carried on indicate that the outfit should have not less than a $3\frac{1}{2}$ -horsepower engine and to operate one gun. Without this sort of capacity the gun delivers a coarse spattering spray which drenches the foliage. There is also a remarkable difference in the character of the spray produced by a 10-horsepower sprayer as compared with the standard $3\frac{1}{2}$ -horsepower outfit. The former breaks up the spray much better and gives it more life. Efficient operation of the gun also requires not less than 250-pounds pressure. This represents a good load for all-day spraying with a $3\frac{1}{2}$ -horsepower outfit, but greater pressure may be obtained without overloading the engine where more horsepower is available. A 10-horsepower sprayer will carry two guns nicely.

In tests carried on with guns shown in Fig. 13 some were found to be superior in some respects, and decidedly inferior in others. The capacity, the distribution of the spray, the control, the distance to which the spray may be thrown and the weight of the gun are all of importance.

When a gun has good capacity (not the greatest), distributes the spray evenly and in fine particles, has an easy, rapid control, a fine drifting spray for close work, and maximum height for long-range spraying it combines the qualities most greatly desired. In weight guns average $3\frac{3}{4}$ pounds. Comparatively few of the guns now available combine all of these qualities to a high degree, but nearly all of them have been improved since they were first introduced. If growers continue to use it extensively, further improvements will doubtless be made.

*Solid-stream Nozzles for Shade-tree Work.*¹ When shade-tree spraying in Eastern states became one of the most important branches of spraying work because of the brown-tailed moth, gipsy moth, and the elm-leaf beetle, an attempt was made to use the sprayers then employed for orchard spraying, but even with

¹ U. S. Bul. 480, Solid Stream Spraying against Gipsy Moth and Brown Tail Moth in New England, by L. H. Worthley.

a tall tower, a bamboo rod, and a nozzle giving a coarse driving spray such as the Bordeaux, the equipment proved inadequate

for this sort of work. Ladders were then employed, enabling the operator to reach the branches and then climb higher by means of creepers. This necessitated long lines of the lightest hose suited to the purpose. With a good operator on the job this method proved to be fairly effective, but it was both slow and dangerous and these factors made it expensive.

Those interested in the work then turned their attention to developing a solid-stream nozzle which would carry spray for a long distance. From the old garden nozzle of the solid-stream type was gradually evolved the efficient type now in use and known as the Worthley nozzle. This is made in two sizes, essentially the same in design, but one is adapted to smaller power outfits. The smaller size is about 41 inches long and carries a removable nozzle or jet $3\frac{1}{2}$ inches long.

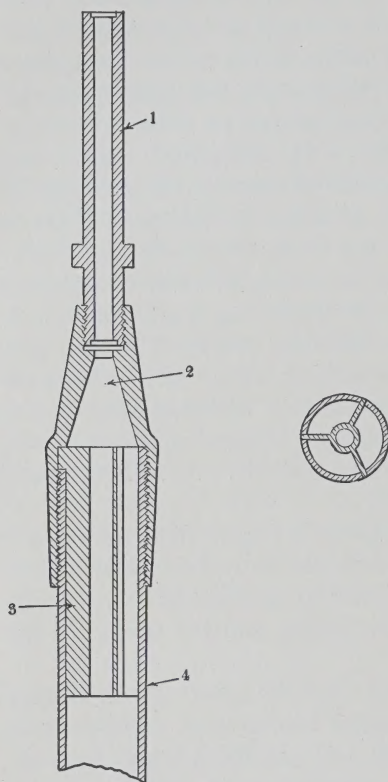


FIG. 49.—Sectional Drawing of Upper End of Worthley Nozzle.

- | | |
|-------------------|-----------|
| 1—Tip | 3—Hopkins |
| 2—Condensing Head | 4—Tube |

The jet carries a smooth bore and is supplied in various sizes as follows:

- $\frac{1}{8}$ in., delivering 6 gals. per minute.
- $\frac{3}{16}$ in., delivering 12 gals. per minute.
- $\frac{1}{4}$ in., delivering 25 gals. per minute.
- $\frac{5}{16}$ in., delivering 45 gals. per minute.

Each tip or jet is threaded and can be quickly screwed into

the barrel of the nozzle. These tips are all bored from solid metal, insuring a smooth waterway. As water passes through lines of hose it takes on a spiral motion, owing to the spiral winding in the manufacture of the hose. To overcome this rotary motion of the water a fin-like device, called a "hopkins," is placed near the end of the nozzle barrel just before the stream passes into the tip or jet. With a sufficient pressure behind the nozzle it is possible to spray shade trees 100 feet in height. The force of a

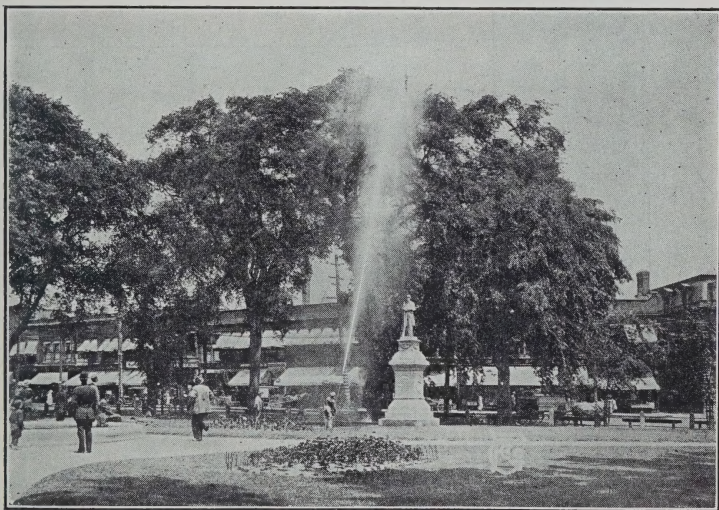


FIG. 50.—Worthley Nozzle in Operation. Has a $\frac{5}{16}$ -inch tip.

stream which carries to that height is so great that when small trees or the lower limbs of large trees are sprayed a device is necessary for breaking the force of this stream. A strip of brass 10 inches long and $1\frac{1}{4}$ inches wide, slightly curved, and called a spreader, is attached to a ferrule about a foot in length so that it can be moved up and down the tube of the nozzle. When the brass strip is pushed beyond the tip the solid stream as it comes in contact with this device is broken up into a fan-shaped stream and the result is a satisfactory mist spray.

These nozzles have a full way shut off near the point where the hose is attached and this is packed on both sides to prevent leakage.

On the large size nozzles a swiveled handle is provided to allow

the nozzleman to turn it freely without being hampered by a twisting hose.

Spray Rods. For many years a part of the standard equipment on a spray outfit has been the extension rod. Each lead of hose on the outfit requires a rod of some sort. These rods vary in length from 6 to 14 feet and are adapted to reach the upper and inner portions of the tree. They may take the form of an

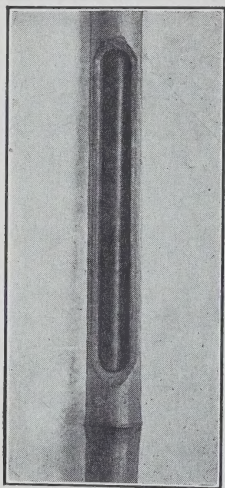


FIG. 51.—Bamboo Rod with Section Cut Out to Show the Pipe which Lines the Rod.

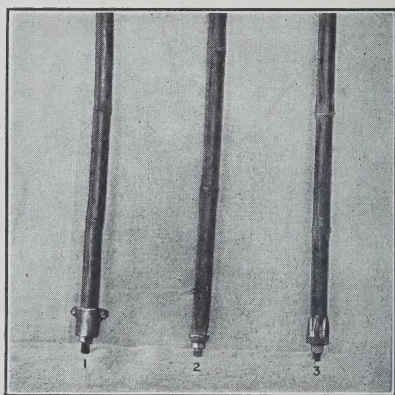


FIG. 52.—Bamboo Rod End Clamps.

iron pipe of $\frac{1}{2}$ -inch size, or bamboo lined with an iron, brass, or aluminum pipe. The bamboo type is lighter to handle, gives a better hand grip for the operator, and is usually purchased in preference to the heavier iron rod, although the latter is cheaper and does not break so easily.

If a bamboo rod is to be purchased, care should be taken to select one which is made properly. The thread on the extension rod to which the hose is coupled is sometimes cut on the frail tubing within the bamboo. The strain placed upon this tubing from dragging the hose through the orchard is very great, and it may be impossible, moreover, to direct the angle of spray at the nozzle by turning the rod, because the tubing and not the entire rod is turned in the movement. This nullifies the value of an

angle nozzle and the construction greatly reduces the durability and value of the rod. Most bamboo rods now on the market are properly made, but a few are still of weak and improper construction, similar to the description given above.

A rod which is properly constructed has a metal sleeve which fits over the end of the bamboo and allows for tightening or loosening by means of screws or bolts. The type which fits as a complete collar around the bamboo is preferable to the sectional sleeve which is virtually five clamps fitting over the end of the rod. If the bamboo dries out, any type of sleeve will become loose. The type which may be tightened by screws may easily be adjusted properly, but the type composed of clamps is usually pounded together with a hammer which often splits the bamboo and is therefore undesirable.

In apple orchards the usual length of the rod is 10 feet. In exceptional cases rods 12 or 14 feet long are used, but such lengths make the work of the operator much more difficult. In peach orchards 8-foot rods are used. For tower purposes a rod 6 feet long is usually preferred, while for small fruits and truck-garden spraying specially designed rods about 3 feet long are sometimes preferred. Frequently iron rods are used for this purpose, and a better grip on the rod is assured when it is wrapped with tire tape, or a piece of rubber hose is fitted over it.

Drip Guards. A special bit of equipment which is frequently used on a spray rod is the drip guard. As sold by dealers it is usually a rubber collar which fits over the end of the spray rod and is slipped down below the nozzle. When it fits fairly tightly it prevents spray material from running down the rod to the operator's hands. In cold weather a wet rod is obviously disagreeable to handle. In warm weather when lime-sulphur solution is used, a wet rod burns the operator's hands. Drip guards cost only about twenty cents apiece and suitable leather guards may be made from old leather on the farm. Because of their convenience they are worth many times the work and cost involved to put them on the rod.

Cut-offs. A cut-off at the base of the spray rod has long been considered a necessary accessory to allow for adjusting or cleaning nozzles or preventing waste of material while moving the outfit to the next point of operation.

Four types are used more or less, the one selected depending

on the type of outfit used and the preference of the owner. Many users place greatest emphasis on the ease, quickness, and completeness with which the liquid is shut off under pressure. This and other special features are discussed under each type. All designs are made of a non-corrosive alloy to withstand the action of spray materials. Because this alloy is soft it wears quickly and in types requiring packing the cut-off must be repacked frequently.

Box or Lever Cut-off. Probably the oldest cut-off now in use is of the box type which resembles the kind of water faucet with a

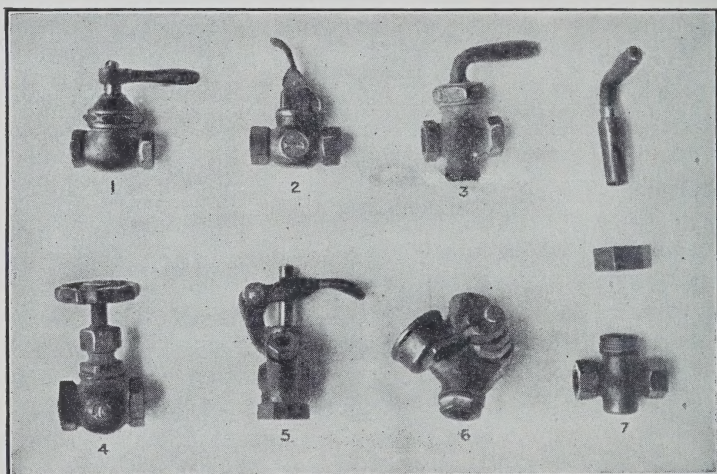


FIG. 53.—Cut-Offs.

- 1—Ball-valve Type. Requires Half Turn to Open or Close
- 2—Disk Valve. Easy to Operate but Useful Only on Small Hand Outfits
- 3—Box type. Common Type. Requires Quarter Turn to Open or Close
- 4—Globe Valve. Does Not Operate Quickly
- 5—6—Angle Types. Operate Easily and Quickly
- 7—Box Type. Taken apart Showing Its Construction

lever which shuts off the flow of liquid with a quarter turn in either direction. It is easy to operate and shuts off the liquid quickly. The term leakless is often applied to it and so far as cutting off the flow of the liquid toward the nozzle is concerned, this term is appropriate. However, the cut-off used for orchard spraying which will not leak at some point, either due to the need of repacking or due to sediment which unseats the valve, has never been made.

The box cut-off is sold by most dealers and is widely used and liked. Before buying one, be sure to examine the waterway.

If it is of the narrow slit type it will greatly reduce the flow of liquid as well as the pressure at the nozzle. Comparatively few cut-offs are now offered for sale having this small waterway, but it is always safe to examine the article when buying.

Globe Valve Cut-off. This type is the slowest of all cut-offs except the gate valve to operate, as it takes several turns to shut off the flow of the liquid. It is of the ball valve type and, like the box cut-off, it requires repacking at intervals. The gate valve is so slow that it is seldom used now as a cut-off.

Ball Valve Cut-off. This is a more recent introduction and the claim for it is that it opens more quickly than the globe type, requiring less than a full turn of the handle, and that it will not leak due to wear, because of the revolving ball on the valve. However, in the field, sediment will sometimes collect between the ball and the valve seat, thus preventing the ball from seating properly. This is indicated at the nozzles when the valve fails to stop the flow of liquid completely. The waterway in this cut-off is neither as large nor as straight as is desirable.

Angle Cut-off. This recent introduction seems to be popular among growers, and perhaps the ease with which the flow of liquid is checked or instantly released may account in part for its popularity. It is probably the easiest and quickest type to operate, and it is so constructed that pressure helps the operator to control the flow of liquid.

All cut-offs of this type are made so that the hose is attached at an angle allowing it to hang in a natural position and thus reducing wear at the coupling. The angle of the waterway causes some friction, but the pressure reduction is not great because the passage is sufficiently large.

Discharge Fittings. A completely equipped spray outfit usually includes a cut-off at the pump. On hand outfits when two leads of hose are used, a stopcock may be provided for each lead. While this arrangement is convenient on hand outfits it is not so important there as with power outfits where it is sometimes convenient to allow the engine and pump to run so that agitation may be provided for the mixing of Bordeaux at the refilling station. In such instances the stopcock allows the removal of hose in the orchard, thus reducing the wear that comes from dragging the hose. It may be of greater importance to cut off one lead of hose to repair a leak or to replace a connection

while the other lead still operates. In such and in similar circumstances the shut-off at the pump is obviously convenient.

Many power outfits are now equipped with double-discharge stopcocks, and this type is cheaper than two singles and usually just as useful.

For the sprayers of ordinary capacity the various types of cut-offs just discussed are satisfactory, but for the larger types of power sprayers now being built or for the high-power sprayers used in

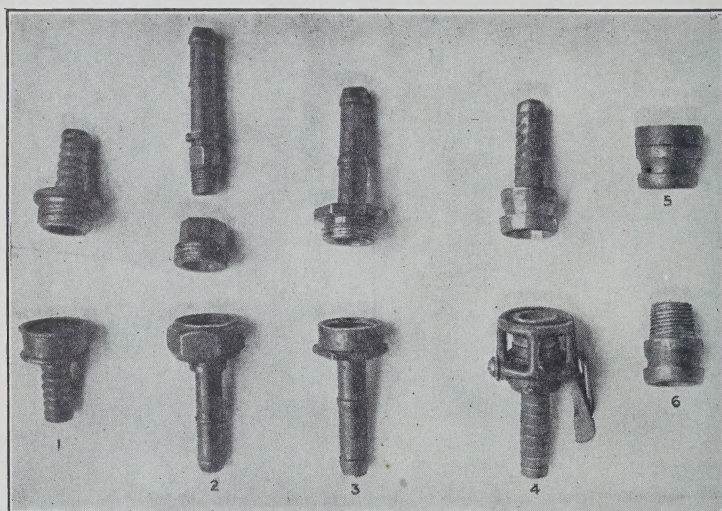


FIG. 54.—Couplings.

- 1—Common Garden-hose Coupling. Worthless for Spraying Purposes
- 2—Good Type of Spray-hose Coupling. Divided Metal Hose Clamps may be Used with This Coupling. Note the Long Shanks and Durable Construction. The Male Half of Coupling is Threaded with $\frac{1}{2}$ -inch Pipe Threads, but by Means of a Bushing as Shown Above It may be Connected to Fittings with $\frac{1}{2}$ -inch Hose Threads
- 3—Another Type of Spray-hose Coupling. Divided Metal Clamps Cannot be Used with This Type
- 4—Quick-change Hose Coupling
- 5—Male Half of No. 4, with Inside $\frac{1}{2}$ -inch Hose Thread which Fits on Sprayer-discharge Pipe
- 6—Male Half of No. 4 with Outside $\frac{1}{2}$ -inch Pipe Thread

shade-tree work, valves of adapted design should be used which have a large smooth bore for a waterway and which are so constructed as to eliminate all crooks and turns and any other form of friction which will reduce pressure at the distant nozzle.

Hose Couplings. There is a wide assortment of hose couplings and clamps which differ in the materials from which they are made and in design, weight, and durability. Yet each type may be

useful and proper in its own limited field. The common short-tailed coupling used for garden hose is all right for that purpose, but more or less of a nuisance when used with spray hose.

The commonly accepted type of coupling for orchard sprayers, especially those where the pressure requirements are fairly high, are of the long-tailed coupling type. Such couplings are superior to the garden-hose type because they withstand higher pressures and give better support to the hose at a point where it is subject

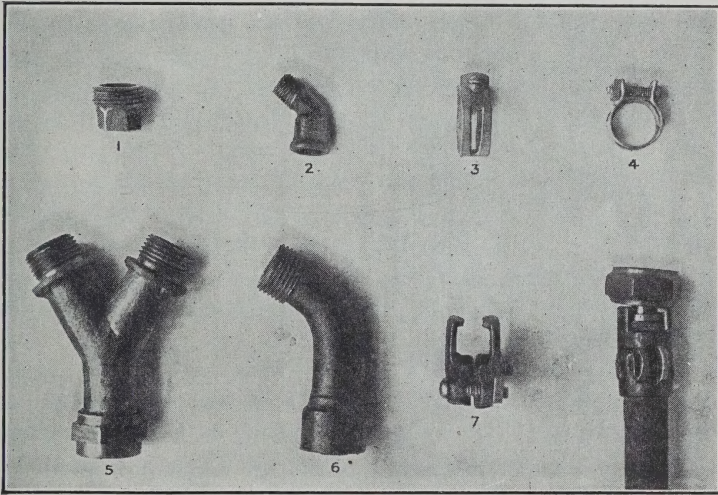


FIG. 55.—Miscellaneous Fittings.

- 1—Reducing Bushing $\frac{1}{2}$ -inch Male Pipe to $\frac{3}{4}$ -inch Female Hose
- 2—Nozzle Ell. For Connecting Straight Nozzles to the Rod
- 3—Hose-band Clamp
- 4—Discharge Y
- 5—Gooseneck
- 6—Divided Clamp
- 7—To Illustrate Method of Attaching Divided Clamp.

to tremendous strain and wear. Most couplings of this type have a substantial divided metal clamp which may be tightened by means of bolts with which it is equipped. Instead of the divided metal clamp as a device for gripping the hose to the shank or tail of the coupling, wire may be substituted. It is wound tightly around the hose in two places, grips it with great tenacity, and in a manner similar to hose bands. The advantage of this type is that there are no bolts or nuts to lose, and in case of breakage, a pair of pliers and a little wire is all that is needed to repair the coupling.

For the pressures usually developed with orchard sprayers these couplings are adequate, durable, and satisfactory. However, when pressures run up to 500 pounds this type would blow out. For hose of small diameters, such as $\frac{3}{8}$ or $\frac{1}{2}$ inch, two brass clamps or metal hose bands on long-tailed couplings are most often used. If these bands are of the proper size they will clamp the hose tightly enough to withstand these pressures. In fact, in certain tests which we have conducted they have withstood pressures of nearly 1000 pounds. Ill-fitting bands, especially when they are too large, will, however, cause a great deal of trouble. Their ability to withstand high pressures are their greatest asset. Some hose bands are made of brass, a soft alloy, and will not withstand rough usage. Steel bolts instead of brass should always be used with these couplings. When these bolts have been tightened sufficiently the portion of the bolt beyond the nut may be filed off and the nut headed to prevent loosening. This type of clamp is frequently used with hose which runs into hundreds or thousands of feet in length on that portion of it which is not more than $\frac{1}{2}$ or $\frac{5}{8}$ inch in diameter and on which high pressures are exerted.

For hose of large diameter, usually 1 inch or $1\frac{1}{8}$ inches, as used for high-pressure shade-tree spraying, a special coupling has been designed. Nearly all long-tailed couplings of the type referred to above have small waterways which are a source of trouble if used in solid-stream spraying. They reduce pressure at the nozzle because of the coupling friction, and may contribute also to leaky hose at the coupling. Hose bands have also been known to cause trouble in work where the highest pressures are required because these bands, if tightened sufficiently to withstand these pressures, may cut the inner tube of the hose, allowing the solution to get into the fabric and causing the inner walls to collapse. Special couplings used for this purpose are guaranteed not to blow out and they grip the hose in a way which will not injure the inner tube.

A special device has also been added to this type of coupling when attached to hose 1 inch or greater in diameter. This device allows for making an instantaneous coupling at the machine and is commonly known as a quick-hitch coupling. This is a great convenience as the long leads of hose may be detached from the spray machine at a point where operations are to be resumed after the tank is filled.

A new type of hose coupling which is very convenient is the quick-change coupling. Its greatest advantage over other couplings is the ease and rapidity with which hose equipped with this coupling may be attached to or removed from the spray outfit. Other advantages are that it does not leak and that there are no gaskets or washers to get lost. It is so constructed that the greater the pressure exerted at the point of coupling, the more firmly is it held in place.

This quick-change coupling may be used to connect two lines of hose together, but is used chiefly to connect hose to the spray outfit. The female half of the coupling is equipped with a rubber tube which slips into the male half. The pressure expands the rubber tube and makes a tight and leakless connection. A durable spring clamp on the female half of the coupling fits over a shoulder on the male half to hold the two parts together.

The male half of the coupling when used to attach hose to the spray outfit has inside pipe threads. Both the male and female portions of the coupling when used to connect two lines of hose together have long tails or shanks which slip into the hose. Hose-band clamps must be used to hold the hose tightly to the coupling.

HOSE

A. Tests on Spray Hose. Many users of spray hose have been in the habit of selecting hose for high-pressure work by ordering 5-ply or 7-ply brands. Ply refers to the fabric incorporated in the rubber walls of the hose. It is included to support the walls against the high pressures which are often developed in spraying with power outfits. There is a great difference, however, in the quality of rubber and fabric used in hose manufacture.

Several years ago tests were carried on at Purdue University using 48 samples of spray hose submitted by thirteen different manufacturers. These samples were tested in triplicate and included everything from garden hose to the best brands commonly used with power outfits in orchard work. A machine designed for testing air-brake hose for railroad cars was adapted for the bursting tests in this instance and it was found that hose of the same diameter and of the same number of ply differed widely in bursting strength. The results of these tests showed that the durability of spray hose depended not upon the number of ply, but upon the

quality of the rubber and of the ply or fabric which went into its manufacture.

The Effect of Spray Materials on Hose. Portions of these samples were immersed in lime-sulphur solution of dormant spray strength. Every other day these samples were removed from the solution and allowed to dry for 24 hours, thus simulating the condition where hose is not cleansed at the end of the day's work, and allowing opportunity for oxidation of the spray material. This process of alternate dipping and drying was continued for 4 weeks and then these samples were tested for bursting strength. In every instance the immersed samples were blown out at a lower pressure than the portions of hose which had not been soaked in lime sulphur. Apparently this solution did not have much effect on the rubber of the hose, but after a time it damaged the fabric or ply considerably.

Other portions from the 48 samples of hose were immersed in miscible oil diluted to the strength recommended by manufacturers for the control of San José scale. Observations were taken daily for a period of 4 weeks, the samples being returned immediately to the solution after each observation. It was soon evident that the oil was having an injurious effect upon the hose. The rubber was gradually separated from the fabric and could be peeled off in small layers with the thumb nail, as it seemed to have lost its elasticity. An attempt was made to determine the bursting strength of these samples, but no couplings could be found which would hold them in place on the machine. In every instance the couplings would pull out, bringing the inside layer of rubber with them.

Hose manufacturers have known for a long time that the strength of a piece of hose lies in the quality of duck or fabric used and the manner in which it is made, and growers are now realizing the importance of selecting good hose. If each ply does not take up the strain where the ply underneath leaves it, it is not serving its purpose of strengthening the hose walls. Furthermore, a 5-ply duck hose will stand a greater bursting pressure than an 8-ply or 10-ply sheeting hose, because the duck represents a better quality of fabric than sheeting.

Perhaps at some future time the manufacture of spray hose will be standardized, and dealers will order this accessory in accordance with a set of specifications similar to those now used

by railroads in purchasing air-brake hose or as used in the purchase of steam hose secured for commercial purposes. The fact that the uses for hose are becoming more numerous makes this a matter of more than passing importance. Rubber hose¹ is now used with paint guns and special sprayers for painting mesh-wire factory fences, tanks, machinery, car trucks, underbodies, castings, ships, bridges, structural iron work, concrete and masonry surfaces. The efficiency of man labor is thereby increased eight to ten times.

B. Size, Weight, and Serviceability of Spray Hose. When lightness in hose is consistent with durability it is highly desirable to choose light hose. A few grades of hose which are light in weight are at the same time made of the best material, so that they withstand the highest pressures for hose used on orchard outfits. The heavy, bulky leads of hose with which some sprayers are equipped are not as durable as the grades just described, yet some people buy heavy hose, believing that weight is indicative of serviceability.

The length of service of orchard sprayer hose is 1 to 3 years, depending on its quality and the care it receives. One of the best grades of hose on the market has a record of 12 years' service, and because of its construction it is adapted to spraying at the highest pressures ever used in the field. If the grower will balance the greater initial cost of high-quality hose against the term of service and the resulting reduction of hose troubles, he may often find it economical to buy this grade or something approaching it. Not in every instance, however, will it be advisable for a man to buy the more expensive brands, and each grower must decide for himself.

Spray hose increases rapidly in weight as the diameter increases. This is clearly shown in the accompanying table prepared by Professor F. C. Sears of the Massachusetts Agricultural College.

One hundred feet of 1-inch, 8-ply, cotton-covered hose,² such as is used in shade-tree spraying, weighs 84 pounds and carries 4.8 gallons of water weighing 32.64 pounds, making a total weight of 116.64 pounds. It is therefore necessary to assign a man to carry every 100 feet of hose used in field work.

¹ India Rubber World.

² U. S. D. A. Bul. 480.

TABLE II

COMPARISON OF WEIGHTS OF HOSE OF DIFFERENT SIZES *

Length Ft.	Size In.	Kind of Hose	Weight, Empty Lbs.	Weight, Full Lbs.
25	$\frac{3}{4}$	Rubber	10.87	13.56
25	$\frac{1}{2}$	Rubber	6.66	9.16
25	$\frac{1}{4}$	Rubber	4.11	4.45
25	$\frac{3}{16}$	Special Cloth Covered	1.00	1.75

* Productive Orcharding, F. C. Sears.

Some have felt that a hose $\frac{3}{8}$ inch in diameter is the smallest waterway which will do satisfactory work in orchards, but other growers are using hose of $\frac{1}{4}$ -inch diameter on hand outfits with entire satisfaction. On power outfits fitted with two disk nozzles or a spray gun a hose of larger diameter must be chosen, $\frac{1}{2}$ inch being a popular size. Whatever the hose requirements in pressure and capacity, the operator will find his work less tiring if he chooses the smallest hose which will meet his requirements. There is a certain amount of prejudice against hose of small diameter among orchardists because some operators feel that it causes reduction of pressure at the nozzle. Some reduction doubtless occurs where the nozzle capacity is greater than the hose will deliver, but in other instances this reduction is due to a waterway in the cut-off which is smaller than that in the hose. This applies to hose less than 100 feet in length.

For greater lengths, such as may be required in shade-tree and woodland spraying, friction may cause considerable loss of pressure before the spray material reaches the nozzle. Since it is very important to maintain a pressure of 225 pounds at the nozzle in this work a table has been worked out which shows the pressure necessary at the machine for various diameters of nozzle-tips and varying lengths of hose.

The table which follows is the result of a long series of tests carried on by the U. S. Department of Agriculture under the direction of H. L. McIntyre.

TABLE III

PRESSURE TABLE FOR WORTHLEY NOZZLE *

To indicate the pressure needed at the pump to give a minimum pressure at the nozzle of 225 pounds.

Size of Hose, in.	Size of Tip, in.	Increase in Pressure, Pounds per 100 Feet
1	$\frac{1}{8}$	2
1	$\frac{3}{16}$	$5\frac{1}{3}$
1	$\frac{1}{4}$	11
1	$\frac{5}{16}$	25
$1\frac{1}{8}$	$\frac{1}{8}$	3
$1\frac{1}{8}$	$\frac{3}{16}$	9
$1\frac{1}{8}$	$\frac{1}{4}$	19
$1\frac{1}{8}$	$\frac{5}{16}$	33

* Published with permission of U. S. Bureau of Entomology.

When a $\frac{1}{4}$ -inch tip is used on a solid-stream nozzle it is impractical to use over 1500 feet of 1-inch hose, and with a $\frac{5}{16}$ -inch tip not over 600 feet should be used.

C. Spray Hose for Hand-sprayer Outfits. The cheapest grades of hose, if replaced often enough, might do for low-pressure hand sprayers, although they will not meet the requirements of lightness or durability. But even here their use would be doubtful economy, when one considers what costly delays hose troubles may bring in spraying season. As the size and capacity of the outfit increases, the need for good hose becomes greater.

When equipping a barrel or tank pump outfit with hose, get plenty of it. The 10- to 15-foot lengths with which these outfits are sometimes equipped are entirely inadequate. At least 25 feet are necessary to do good spraying, some prefer 35 feet, and where two leads of hose are in use, one might well be 50 feet long.

D. Spray Hose for Orchard Power Sprayers. The hose pressure for hand-sprayer outfits will not often exceed 150 pounds, but with power sprayers the pressure will sometimes run as high as 350 or 400 pounds. The usual pressure, however, is somewhere

between 200 and 300 pounds. Since the pressures differ from those obtained in hand outfits the hose requirements are correspondingly different. It will usually be found desirable to purchase the best grade of hose offered with the orchard power sprayer. Most outfits of this sort will carry at least two leads of hose, one of which should not be less than 50 feet long and the other preferably 35 feet or longer. The exception to this length of hose will occur when one man works from a tower. In that case, the hose should be just long enough to permit the operator to work freely from that position without having extra hose to bother him.

E. Spray Hose for High-pressure Purposes. Modern methods of pest control require the development of very high pressures in forcing the spray material through the hose to the nozzle. An instance of this may be cited in spraying a cranberry bog. The power sprayer is stationed on the bank at one side of the bog and a line of hose 1 inch in diameter and 1000 to 2000 feet long is laid. To this is coupled another 1000 to 2000 feet of $\frac{3}{4}$ -inch hose and finally 2000 or 3000 feet of $\frac{1}{2}$ -inch size. A high-powered sprayer is necessary which will develop from 400 to 600 pounds pressure. This pressure is necessary at the machine in order to develop the desired 200 pounds pressure at the nozzle. Every effort is made to reduce friction by the use of large pumps and large waterways in the construction of the outfit and various accessories. Although certain orchard sprayers may develop 400 pounds pressure or better, they are not suited, as a rule, to this high-pressure work because of the larger amount of friction due to small piping, too many crooks and turns, and, in general, to small waterways.

In spraying shade trees the most satisfactory pressure is 225 pounds at the nozzle, and the special nozzles required will be discussed under the heading of nozzles. Trees vary in height up to 100 feet and nozzles must be adapted according to the height.

In some instances trees must be sprayed at long distances from the machine and lines of hose 1 inch in diameter are sometimes laid 7000 to 8000 feet where spraying must be done on hills or at that distance from the nearest water supply. In order to have 225 pounds pressure at the nozzle, 1000 pounds must be carried at the machine. Where the machine must be placed at the foot of a hill it sometimes takes 400 pounds pressure there

before any liquid will pass through the nozzle at all at the top of the hill. In some instances if the by-pass or pressure regulator is not working absolutely right the pressure on a part of the hose may run as high as 1250 pounds.

One leading manufacturer of spray hose for high-pressure work has three classes of this hose which are made according to the pressure requirements. One class of hose is used on a motor-truck sprayer on which the maximum hose-pressure requirements are 550 pounds. The hose used for larger sprayers is a better grade, to withstand pressures of 700 to 750 pounds. A still better grade of hose is required for a 5-ton chassis on which the pressure requirements may range from 1000 to 1250 pounds. Obviously the couplings used must be of special design to withstand the tremendous pressures and the strain and torsion which comes from dragging the long leads, and these points are discussed under the head of hose couplings.

In general, the highest grade of hose is the cheapest for this work, but unless high-grade 10-ply hose¹ is used, having a heavy inner tube and outer walls, it will be well to get 7- or 8-ply hose covered with a cotton jacket treated to increase its durability and to prevent mildew.

F. Special Hose for Oil-burning. Oil-burning as a method of insect pest control is being used to a moderate extent by the U. S. Department of Agriculture as one means of controlling European corn borer and Japanese beetle. It is useful because of its rapidity and because more thorough burning can be accomplished than by the ordinary method. In winter burning of the hibernating quarters of the chinch bug the use of an oil flame is of special value in localities where the grass remains partially green during the winter or where thoroughly dry conditions are not always obtainable.

In this work oil is pumped from a tank through a lead of hose to a metal rod at the end of which the oil is ignited by means of some form of torch.

No grade of hose previously considered is thoroughly satisfactory in oil-burning because the oil soon eats the tube and then leaks out through the fabric. Oil hose has a specially prepared tube in which oil is mixed with the rubber in the manufacturing

¹ U. S. D. A. Bul. 480, p. 4.

process. This special grade of hose delays the injurious effect on the tube for a considerable time, so that with ordinary care such hose should last two seasons, while cheap hose would last only a few days.

G. Care of Hose. Rubber spray hose depreciates slowly in value when properly used, but very rapidly when abused. Fresh water is usually all that is needed to cleanse it at the end of each day's work or at the end of the season. Abuse may take such apparently harmless forms as failure to cleanse, allowing kinks to form, or driving the outfit over the hose. The two latter treatments break or injure the fabric, and certain spray materials, when allowed to remain indefinitely in the hose, are responsible for curtailing its usefulness because of the effect which chemicals have on the rubber and fabric.

Light and heat are also injurious to rubber, so it is better to store hose in a cool, dark place. It is a common practice to arrange hose in neat coils before storing, and with the grades used for the orchard and garden, this method is not very harmful, especially when the coils are hung over any object which distributes the weight. Hanging on a nail, for instance, will form a weak place, but sawing a nail keg in two and nailing the bottom to the wall makes a fine hanger for hose.

The heavy grades of hose used for shade-tree work must often be coiled in transit during spraying season, but coiling for winter storage should be avoided.

Pressure Gauge. The pressure gauge has developed from a mere convenience to a necessity on power outfits. It is especially important where a spray gun is used to maintain a pressure of at least 250 pounds. With a rod and nozzle in orchard work most growers maintain a pressure of about 200 pounds. In spraying potatoes effectively where leaf hoppers are present the latest recommendations indicate that nothing less than 200 pounds pressure will prove efficient. In orchard work this high pressure is not absolutely necessary, as a good rodman may spray efficiently if he has a steady pressure of 100 pounds or better when using a small orifice in the disk of the nozzle. Maintaining pressure on a hand pump is heavy work, and the tendency is for the operator to let the pressure get low. A pressure gauge may be a hard task-master at the pump handle, but it usually insures greater and more even pressure for the rodman. Depending on the make of pump

it should be possible for a man to maintain a pressure of from 100 to 125 pounds. With tank pumps it will be possible to maintain a pressure 25 to 50 pounds higher with about the same amount of effort.

Tank Fillers. In orchards of commercial size the problem of refilling a spray tank in the quickest possible manner is an important one. With certain serious insect pests and fungous diseases the interval during which effective work may be done is limited to a few days, as, for instance, the first summer spray for scab and the blossom spray for codling moth. The amount of work which can be efficiently done by one machine is also limited, and it should be the aim of the grower to keep a sprayer in operation just as much of the time as possible. In certain orchards it has been found that fully half of the time of each working day is spent in going to the filling station and returning to resume operations. When the filling station is more than a quarter of a mile away, probably more time will be spent in refilling than in applying the spray.

Some growers eliminate a good deal of this waste of time by the use of a tank wagon. This outfit brings the spray mixture to the sprayer and the only added expense is for a team and driver, thus nearly doubling the efficiency of the spray machine since it takes only about 6 to 10 minutes to reload in this manner, where it would take $\frac{3}{4}$ of an hour to go to the filling station. A spray machine having a 200-gallon tank with a pump capacity of from 6 to 10 gallons per minute will discharge its load in from 21 to 35 minutes. This time does not allow for the periods when the nozzle is shut off or for other delays.

There are various kinds of tank wagons in use—some equipped with hand pumps, others with engines, and some wagons with only a tank. In the latter instance the spray machine is equipped with a tank filler. In this brief discussion of accessories it is not possible to consider fully the various types, but both the hand pumps and power outfits have a place in commercial work.

A cheap, serviceable tank wagon may be assembled by using a cart or wagon kept for general farm purposes and loading used lime-sulphur barrels on it. A hole should be made in one end of each barrel sufficiently large to accommodate the hose filler from the spray outfit. To prevent barrels from tipping off, the wagon should have sides or improvised braces. Five barrels of 45- to 50-

gallons capacity are needed to fill a 200-gallon tank, for the filler will not remove the last few gallons at the bottom of a barrel.

A highly efficient tank filler has been constructed by the Perrine Brothers who have 130 acres of apples in Centralia, Illinois. This outfit is illustrated in Fig. 56, where the tank filler which holds 400 gallons of liquid is shown filling a 300-gallon tank on the spray outfit. It takes only about 3 minutes to do this and but 4 minutes to load the tank filler. According to Mr. Perrine the minimum

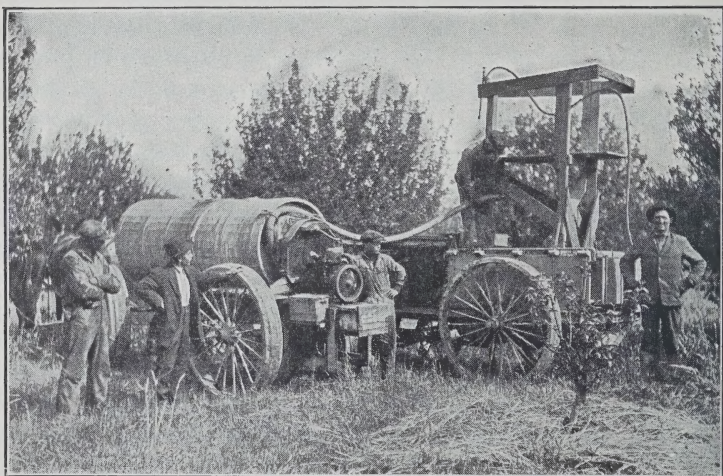


FIG. 56.—A 400-gallon Water Conveyor which Fills a 300-gallon Spray Outfit in Three Minutes. Both Machines are Equipped with Extra Wide Sectional Rims for Soft Ground. The Tower is Considered Indispensable for Trees More than 22 Feet Tall. The Sprayer has a 15-H.P. Engine which Operates Two Large-capacity Guns.

amount of material delivered to spray outfits by this tank filler in a day is 5000 gallons and as high as 10,000 gallons are sometimes supplied. He writes, "We think that the conveyor saves two or three spray rigs and the men and teams it would take to run them. If the orchard is a half a mile or more from the filling station the conveyor cannot quite keep the two rigs running all of the time. We use spray guns on our outfits. The conveyor is pulled by two good mules except just after a rain when we put on three. We find the conveyor especially convenient when self-boiled lime sulphur must be used, as we can make it in 400-gallon batches."

Where the acreage is not so large and the water supply is in close proximity to the orchard in the form of a cistern, pond, irrigation ditch, etc., the expense of tank wagons and extra labor may be lessened by using a tank filler. Manufacturers of spray machinery offer these fillers either as part of the sprayer equipment or as an extra. It is reasonable in cost and can easily be transported on the outfit at all times. These fillers are made in different sizes. Some firms offer three sizes for sale, depending on the pump capacity of the outfit. The capacity of a filler for one make of triplex pump may be illustrated in the following table.

TABLE IV

Pump Pressure	Lift	Discharge Capacity
250	3 ft.	40 gals. per minute
250	7 ft.	35 gals. per minute
250	10 ft.	30 gals. per minute
250	15 ft.	25 gals. per minute

This filler is of the ejector type, equipped with a long suction hose, which draws the water into the spray tank from whatever source is available. Enough liquid must be left in the spray tank to create a suction before water may be lifted, and care is necessary to see that spray materials are not siphoned into a well or spring before or after the tank is filled.

In irrigated orchards the rotary pump is used as a tank filler. This type is composed of gears over which is fitted an air-tight metal casing, water being lifted to the desired point by suction.

The principle of the rotary, or centrifugal, pump¹ is similar to that of the plunger type, each tooth of the gears or cams acting as a piston. These cams are usually well fitted, and cause but little friction in operation. On lifts over 25 feet high this pump requires comparatively little power, and will work against a pressure of 10 to 50 pounds, which is equivalent to a head of 23 to 115 feet.

Pumps of this type are made of iron and bronze. Those made of iron should never pump anything but water in orchard work, as spray materials will corrode the working parts, and the pump

¹ Ramsower, Equipment for Farm and Farmstead.

will fail to work without priming. A filler which has to be primed is of little value.

The working parts of a rotary pump should be oiled often to prevent rusting, and when put away at the end of the season it should be filled with oil. This type of pump is reasonable in cost.

Overhead Tank System. Probably the overhead system of supplying water to sprayers is considerably more expensive to install than the methods described in foregoing paragraphs. However, it is far more efficient where conditions warrant their installation. A description of the overhead system installed by the Laurel

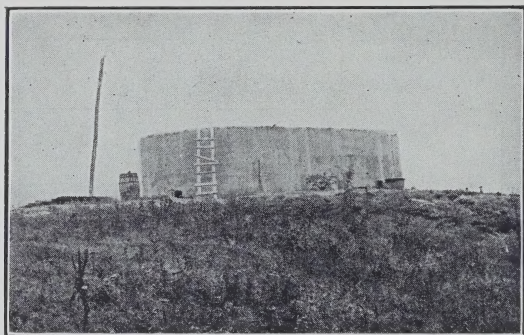


FIG. 57.—Central Reservoir. Water from this Reservoir Goes to all Parts of a 200-acre Orchard and to all Buildings on the Farm. It has a Capacity of 51,000 Gallons.

Orchard Company of Laurel, Indiana, is given below, together with illustrations.

The water for this system is pumped from a well driven below the river bed by a suction pump operated by a $4\frac{1}{2}$ -horsepower gasoline engine located in a power house in the valley just below the orchard. The floor of the power house is about 20 feet above the low water level of the river. The water is pumped about half a mile through a 2-inch pipe to a reservoir 208 feet above the floor of the power house. The capacity of the reservoir is 51,000 gallons. It is located on a ridge which has a higher elevation than any other point in the orchard. Gravity distributes the water from this reservoir through 1-inch pipes to five subsidiary tanks scattered over approximately 200 acres of orchard. These tanks have a capacity of 660 gallons and are kept filling auto-

matically by float valves. Four-inch gate valves conduct the water to the spray outfit and a 200-gallon tank can be filled in less than a minute.

This system was built in 1912 at a cost of \$3350. At the present time it might cost about \$8000 to duplicate it. Last year, in its tenth year of service, only \$250 was expended for upkeep and repairs.

The system has proved highly satisfactory to the owner. At

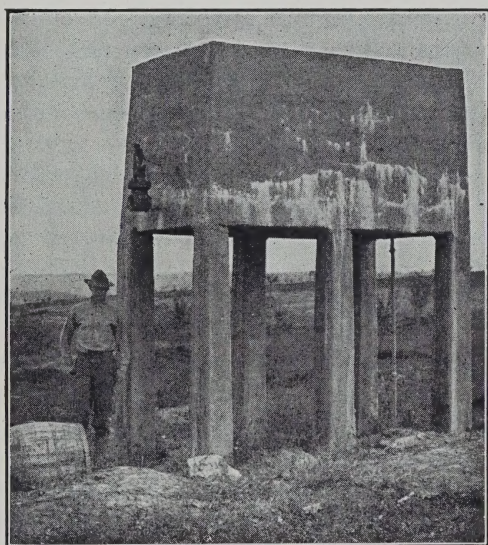


FIG. 58.—Subsidiary Tank. Is Connected to Central Reservoir and has a Capacity of 660 Gallons. It is Equipped with a 4-inch Gate Valve. A 200-gallon Tank can be Filled in Less than One Minute.

each subsidiary tank a supply of material is kept on hand for filling the spray tank, and it takes only 15 minutes from the time a spray tank is emptied until operations may be resumed at the most remote point from any supply tank. When spraying is done close to the tanks the time involved in refilling is much less, of course. Such a system will effect a great saving in time and labor, and among the mature trees in the orchard it is possible to spray out as many as fourteen 200-gallon tanks in a 10-hour day.

Mr. A. L. McClay, who has over 1400 acres of orchard in southern Illinois, finds the overhead supply tanks of great value. He

has seventeen filling stations distributed through his orchards, constructed at a cost of \$10,000. This system increases the number of tanks which each outfit can discharge in a day, and makes each machine more efficient.

Spraying Towers. Just at the present time very few spray machinery companies are advertising spraying towers in their catalogues and inquiries sent to several of these companies brought replies that they had temporarily discontinued making towers because of no demand.

This is apparently the result of the introduction of the spray gun, for growers generally conceived the idea that when they used the gun a tower was not necessary. This idea is a serious mistake, as is explained under the uses and limitations of the gun.

Towers take various shapes and the height will depend upon the needs of the orchard. Certain manufacturers have installed a tower railing on top of the tank on the outfit and even this added height is quite a help when a gun is used in distributing the spray in the top of the tree. With large trees, however, this height of tower will not insure thorough work.

Towers which are square or oblong in shape are most frequently used and are built over the spray tank. The usual height is 3 to 4 feet, but occasionally towers 5 or 6 feet above the top of the tank are used. Where the trees have been planted close together it is difficult to drive through the orchard with a tower of this shape. In such cases a platform may be built, and in place of the railing a padded wooden horse is installed on the platform and the operator straddles this horse.

On large trees the spraying tower is indispensable in effective control of San José scale, apple blotch, and other serious pests. Growers who are careful students of spraying problems are still using the tower and the unsatisfactory results obtained by others will undoubtedly lead to a more general use of this important accessory in the near future. The fact that certain prominent spray machinery manufacturers have decided to resume the construction of spraying towers for the coming season is an indication that we may expect more effective spraying in the future.

Home-made towers are usually built entirely of wood. Towers sold by dealers are usually of steel construction and so made that when not in use the spray outfit may be stored in a shed with a

low entrance by merely removing two braces and folding the tower on top of the tank.

Tools. Probably there is nothing quite so exasperating as attempts to make adjustments on a power sprayer without having proper tools with which to do the work. The outfit may be splendidly equipped in practically every detail except a good assortment of tools. This dearth of tools is not peculiar to spray outfits, but occurs with many kinds of farm machinery and with most automobiles. Vexatious and costly delays may be avoided if the proper tools are at hand. The experienced operator will manage somehow to assemble a good kit of tools and will then see that they are kept in the tool box of the outfit and not in various places. If necessary, he will keep these tools under lock and key. If the grower has more than one spray machine he will provide a working set of tools for each outfit, so that minor adjustments may be made in the field without delay. One set of tools for more extensive repairs will also be kept at headquarters.

SPECIAL EQUIPMENT

A. Extra Parts. The importance of keeping the sprayer in operation as much of the time as possible has already been mentioned. When the acreage assigned to a power outfit is just about up to its full capacity, then the grower naturally has his worries when this outfit must be backed into the shed until he can receive a rush order which replaces a broken part. Growers with long experience have learned that it is money well invested to have certain extra parts for each outfit always on hand in order to prevent such delays. Such parts as are subject to wear or breakage or frequent replacement to maintain efficiency should be kept on hand. Two men who have had years of experience in the field in keeping prominent makes of power sprayers in good working order have submitted items to the writers, listing extra parts for gasoline-power sprayers. These lists were merged into one, as follows:

Pump Parts

- 1 set pump packing.
- 1 set packing for agitator shaft.
- 1 plunger rod.

- 1 plunger bearing.
- 1 valve cover.
- 1 ball for valve.
- 1 valve seat or cage.
- 1 set valve gaskets.
- 3 gaskets for tank filler.
- 2 drain plugs.
- 1 suction screen.
- 1 sediment well screen.
- 1 3-foot brass screen for tank strainer.
- 1 double cut-off for hose attachment.

Pressure Regulator Parts

- 1 diaphragm
- 1 stem.
- 1 adjusting nut.
- 1 valve seat.
- 1 ball for valve.
- 1 valve cover or cap.

Accessories

- 1 gun.
- 1 bamboo rod with cut-off.
- 2 nozzles.
- 1 length of hose.
- 2 hose couplings and clamps.
- 12 hose gaskets.
- 4 nozzle disks and gaskets.

Engine

- 1 spark plug.
- 2 circuit-breaking springs.
- 1 governor latch.
- 1 governor latch spring.
- 1 speed-adjusting thumb screw.
- 2 valve gaskets.

These various parts will cost in the neighborhood of \$45. What does this expense amount to as compared with holding up a

working crew of one to three men and two horses, and lowering the efficiency of a \$500 power outfit, or letting disease and insects get started in the orchard?

When the size of the orchard demands more than one power outfit a full set of these supplies for each machine may not be

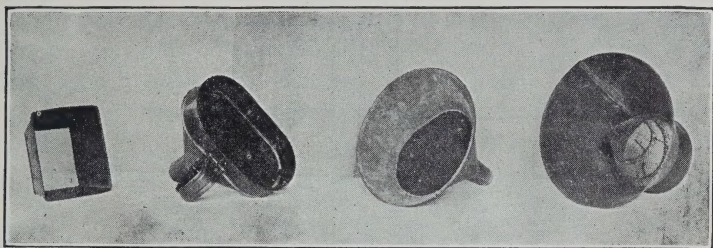


FIG. 59.—Strainers—Flat Screen, Slanting Screen, Cone-shaped Screen.

necessary. The value of having these supplies in sufficient quantity is, however, even greater.

Mr. R. A. Watson of southern Illinois has 3000 acres of orchard, and in order to keep his sprayers at work he has equipped a room much like the cabinet arrangement in an up-to-date hardware store. Each locker or drawer is labeled, and whenever any of the supplies become nearly depleted an order is sent in for more.

He operates about 40 spray outfits and his order for extra supplies in the spring amounts to \$900 to \$1000.

B. Strainers. When the operator has to stop to clean clogged nozzles frequently one of two things is responsible. Either sediment has been allowed to collect for some time in the bottom of the tank and the strainer at the intake is not fine enough to exclude it or the spray material was not properly strained into the tank. The occasions when a strainer is not needed as the material passes into the tank are so rare that they may be ignored.

There are various designs of tank strainers on the market.

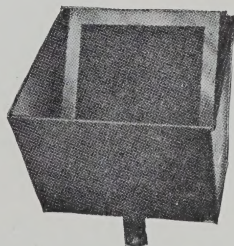


FIG. 60.—A Special Type of Strainer Constructed of Heavy Galvanized Steel and having a Copper Screen. It is not only Built to Withstand Rough Usage, but has Large Capacity.

Those with ordinary horizontal surfaces are not so useful as the ones of cone shape. When the spray material contains a great deal of sediment as, for instance, with self-boiled lime sulphur, the surface of the cone-shaped strainer allows the sediment to collect

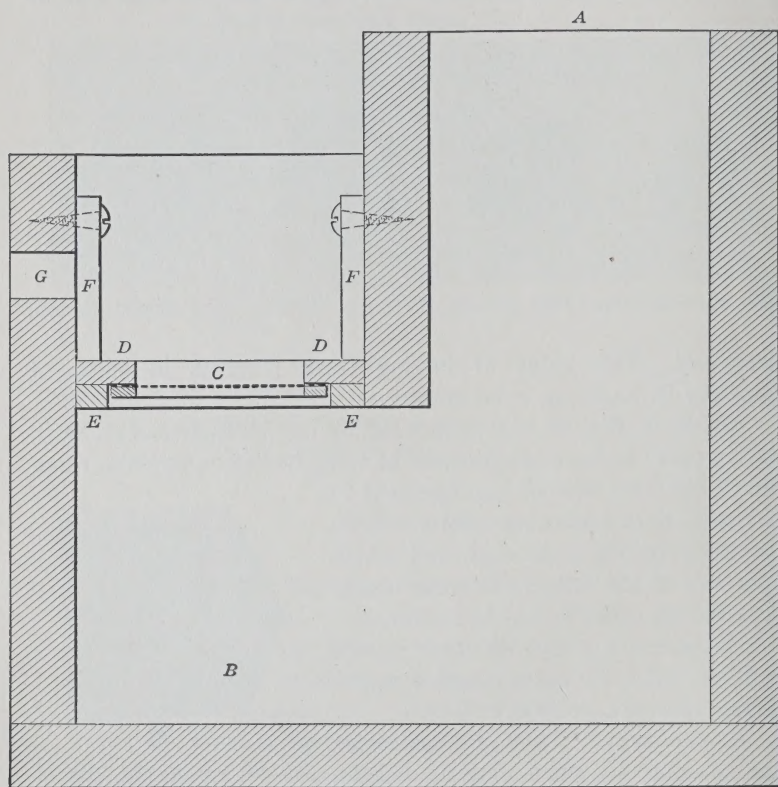


FIG. 61.—Section of a Stewart Strainer. Spray Materials are Poured in at *A* and pass Upward through Screen at *C*. The Coarse Material Collects in the Bottom *B*. The Screen is Fastened to a Removable Frame, *D*. The Frame Rests on the Cleats *E* and is Held in Place by Strip *F*. The Outlet for the Spray Materials is at *G* and Should Be of Good Size.

at the base and the material which will strain through passes on nearer the top of the cone.

A compromise between the cone and horizontal strainers is found in the design which fits the strainer in the frame at an

angle of about 45 degrees. This is somewhat better than the horizontal, but hardly as good as the cone.

For self-boiled lime sulphur a strainer which has capacity is important. If considerable time must be allowed for filling a 200-gallon tank with the ordinary strainer it does not take long to pay for a special one with greater capacity.

Most good tank strainers are made of copper wire with 15 to 24 mesh to the inch. The mesh of a strainer at the intake to the pump should preferably be finer, the majority being 24 mesh. The latter will need frequent inspection and cleaning. The spray

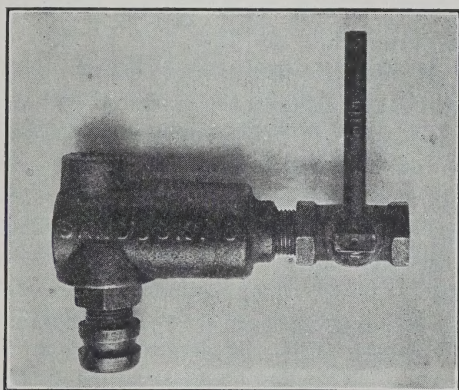


FIG. 62.—Separator. Usually Connected to Discharge Pipe to Intercept Sediment which Would Otherwise Clog the Nozzle. Strainers on Sediment Wells and in Certain Disk Nozzles Serve a Similar Purpose.

materials quickly corrode it and seal many of the meshes, reducing pressure and flow of liquid. Corrosion and hard usage also may cause breakage of the screen, allowing sediment to clog the nozzle. Extra screen should always be kept on hand to make prompt replacement possible.

C. Separator or Nozzle Protector. Any device which will materially reduce the clogging of nozzles is well worth the expense of installation. Such an accessory is the separator or nozzle protector. Two makes are known to the writer, which are used extensively in the orchards and vineyards of Ohio and New York and to a limited extent elsewhere. A description of the simplest design follows, accompanied by a picture, see Fig. 62.

It is essentially a sediment basin with two openings at the top to allow for the direct forward passage of spray mixture, and a box type shut-off at the bottom of the basin allows for the periodical discharge of sediment. The direct flow of spray mixture is impeded only by a sieve or strainer of medium-sized mesh, fitted against the interior wall of the sediment basin, opposite the direction of flow of the liquid. This strainer intercepts any sediment which has passed through the pump and deflects it into the basin. Unless this sediment is discharged periodically the basin may overflow. Each time the spray tank is emptied the nozzle cut-off should be closed and the stopcock on the separator opened, to allow the pressure behind the liquid to force out all sediment while the engine is still running.

A grower may exercise the greatest care to keep fine-meshed strainers in good repair both on the tank and at the intake to the pump and yet clogging of nozzles may sometimes occur. This may be due to poor mixing of spray materials with a resultant heavy sediment, as sometimes occurs with paste forms of arsenate of lead. It may also be due to a heavy, sticky precipitate formed in certain combination sprays or to the chips of fraying or disintegrating gaskets used on connections between the pump and the nozzle. Ill-fitting gaskets are serious offenders in this respect. Even the flakes which form within the waterways may clog the nozzle, and in all these instances vexatious delays may be largely avoided by the use of the separator. Mr. T. J. Barnes, who has used it for years in commercial orchard work in Ohio, states that he converted 23 barrels of concentrated lime sulphur into dormant spray mixture and applied 46 tanks (9200 gallons) of material without clogging the nozzle once.

The separator is especially useful with nozzles, giving a fine mist such as some growers prefer to use for spraying potatoes, vineyards, and stone fruits.

Some outfits are equipped with a sediment well strainer, and some disk nozzles have a coarse-meshed strainer in the eddy chamber. Both serve a purpose similar to that of the separator, but they are not usually so efficient.

D. Bushings or Reducers. Hose couplings sometimes have a male fitting which is, for example, $\frac{3}{8}$ of an inch in diameter, while the female fitting on a spray gun or other connection is $\frac{3}{4}$ of an inch. A bushing or reducer may be used to connect the fittings,

one end of the bushing having a male thread made to fit the larger connection, the other a female thread of proper size to join with the hose fitting.

E. Pails. Pails or buckets are needed for measuring liquid spray materials. The grower will use whatever type is available, but wooden buckets are probably cheapest and damaged the least by corrosive spray materials.

F. Scales. To avoid guesswork a pair of scales should be available for weighing out the spray materials.

G. Hydrometers. The hydrometer is a special instrument devised to test the density or concentration of lime sulphur. The spindle of this glass instrument is usually graduated in two scales—specific gravity and Baumé. When the hydrometer is placed in water or liquids heavier than water the density of these liquids may be determined by the reading on the spindle at the surface of the liquid. Since the Baumé scale is much easier to read than specific gravity this is the one which the grower will use.

A lime-sulphur hydrometer and a glass-testing cylinder may be obtained through local supply men for about \$1.25 or may be ordered direct from any of the manufacturers and dealers in glass and optical instruments.

Even commercial brands of lime-sulphur solution will vary in concentration from 31 to 34 degrees Baumé. Such differences in density will make important differences in the amount of water which should be added to secure the proper strength of spray material. When lime sulphur is home-cooked it is absolutely essential to have a hydrometer for testing purposes, as the concentration of home-made solutions will often vary from 22 to 28 degrees. To use more lime sulphur than is necessary is not economical. To use less sometimes makes spraying a failure. The hydrometer will eliminate guesswork.

How to Use the Hydrometer. Fill the glass cylinder nearly full with concentrated lime sulphur. Lower the hydrometer into it and note the reading at the surface of the solution. To get the proper dilution find your reading on the dilution table which follows, and, depending on whether the application is a winter or summer spray, add the amounts of lime sulphur designated in the table as necessary to make up 50 gallons of spray at the proper strength.

TABLE V
DILUTION TABLE *

When Hydrometer Reads		Winter Spray	Summer Spray
		Use the following amounts of lime sulphur to make 50 gallons of spray for scale control. Should test about 5° Baumé	Use the following amounts of lime sulphur to make 50 gallons of spray for summer sprays on apples, pears, or cherries. Should test about 1° Baumé
Specific Gravity	Degrees, Baumé		
1.318	35	5 gals. 1 qt.	1 gal. 1 pt.
1.306	34	5 gals. 2 qts.	1 gal. 1½ pts.
1.295	33	5 gals. 3 qts.	1 gal. 1 qt.
1.283	32	6 gals.	1 gal. 1 qt. ½ pt.
1.272	31	6 gals. 1 qt.	1 gal. 1 qt. 1 pt.
1.261	30	6 gals. 3 qts.	1 gal. 1 qt. 1½ pts.
1.250	29	7 gals.	1 gal. 2 qts.
1.239	28	7 gals. 1 qt.	1 gal. 1 qt. ½ pt.
1.229	27	7 gals. 3 qts.	1 gal. 2 qts. 1½ pts.
1.218	26	8 gals. 1 qt.	1 gal. 3 qts.
1.208	25	8 gals. 3 qts.	1 gal. 3 qts. 1 pt.
1.198	24	9 gals. 1 qt.	2 gals.
1.188	23	9 gals. 3 qts.	2 gals. 1 pt.
1.179	22	10 gals. 2 qts.	2 gals. 1 qt.
1.169	21	11 gals. 1 qt.	2 gals. 1 qt. 1½ pts.
1.160	20	12 gals.	2 gals. 2 qts. 1 pt.
1.151	19	12 gals. 3 qts.	2 gals. 3 qts. ½ pt.
1.142	18	13 gals. 3 qts.	3 gals.
1.133	17	14 gals. 2 qts.	3 gals. 1½ pts.
1.124	16	15 gals. 2 qts.	3 gals. 1 qt. 1 pt.

* Purdue University Station Bulletin, 194.

Poison Mixer. In connection with the spraying of shade trees for the control of gipsy moth and other serious pests, large amounts of arsenate of lead are used. A large proportion of this arsenical, as used for this purpose, has been put up in the paste form which contains 50 per cent water. Because of its weight the lead quickly settles to the bottom of the container and should be stirred thoroughly before being mixed with water for application. This form of lead is usually obtained in steel drums or wooden

packages, and a mixer has been devised which can be attached to a 100-pound steel drum for the purpose of mixing the lead thoroughly. The mixer is composed of two dashers or churn ladles—one placed near the bottom of the drum, the other about half way to the top. A tripod clamp fits over the top of the drum when the lid is removed, and may be fastened securely in place by means of a threaded crank. By turning another crank similar to the one found on a bread mixer it is possible to mix the contents of the drum thoroughly in from 3 to 5 minutes. Although the arsenate of lead now used may be mostly in the form of powder, it seems probable that this sort of a mixer could be adapted for use with the powdered form.

Shade-tree sprayers are equipped with a mixer very similar in design to the one just described, but it is power instead of hand-driven.

Fittings Designed to Reduce Hose Wear at the Coupling. In addition to the angle cut-off mentioned above as designed to take the strain off the hose at the coupling, we also find metal gooseneck attachments used at the discharge pipe on the pump to relieve hose strain. Where the hose can always be used on one side of the outfit, the gooseneck is useful, but if the hose is dragged in an opposite direction the angle formed is greater than if the coupling were attached directly to the discharge pipe. If a gooseneck could be designed with a swivel such as is used on couplings made especially for high-pressure hose in shade-tree work it would become a very useful accessory in reducing hose strain and breakage.

A simple device which has been used by the Simpson Orchard Company, of Vincennes, Indiana, is as follows:

An extra clamp is fastened around the outside of the hose about $2\frac{1}{2}$ feet from the discharge pipe. A wire is then attached to this clamp and fastened to some part of the sprayer, as illustrated in the accompanying photograph. The length of the wire is less than the distance from the extra coupling to the end of the hose, hence, the strain which comes from dragging and twisting the hose is distributed, but comes mostly on the wire rather than in the usual place around the coupling attached to the discharge pipe.

Widening the Tires in Muddy Season. The early season sprays are often applied with great difficulty, owing to the muddy con-

dition of the orchard. Some growers meet the difficulty by using four horses instead of two, but in large orchards the necessary teams are not available, hiring them is expensive, and often they cannot be secured at any price.

Meanwhile valuable time is being lost, for the time when effective spraying may be done is exceedingly short, and growers rightly count on using their sprayers well up to the limit of their capacity. Necessity for action led one grower to work out a plan for widening his tires and the results are shown in the accompanying picture.

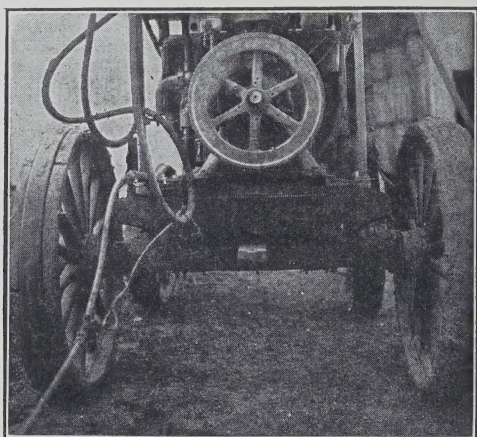


FIG. 63.—Illustrating the Method of Widening the Rims for Hauling the Sprayer Over Soft Ground and Method of Relieving Strain on the Hose.

The felly or felloe of the wheel, which is the wooden rim just beneath the steel tire, serves as an anchor to which is bolted an auxiliary wooden rim or felloe on each side of the wheel. By this means the width of the tires may be more than doubled. Most triplex sprayers have a shipping weight of a ton or more, and when loaded with spray material these outfits weigh from $1\frac{1}{2}$ to $1\frac{3}{4}$ tons. When the ground dries up and again becomes hard, the weight and wear of the rig in motion is borne by the steel rim, for the auxiliary felloes are bolted a fraction of an inch below it.

It is possible to attach extra felloes to wheels made entirely of metal. Pieces of two by four or two by three may be cut into such lengths that when the ends are beveled and joined together

they will follow the contour of the wheel and fit into a position similar to the auxiliaries on the outfit described above. Bolts pass through these felloes closely underneath the steel rims and draw the felloes firmly against opposite sides of the rim. Braces which subtend arcs of the felloe are then fitted into place on each auxiliary thus providing support.

Gloves and Coats and Eye Protectors. Some men become to a certain degree hardened or immune to the discomforts of spraying, while others having more tender skin are always subject to painful burns and blisters from lime sulphur. The concentrated form should be washed off the skin immediately and saturated clothing removed at once, otherwise deep, painful burns and, perhaps, enforced idleness will result. To a lesser degree the diluted solution will also burn.

Rubber or leather gloves are often worn to protect the hands. Rubber gloves are cold and lack durability, while leather gloves, if properly oiled, are satisfactory and may be used for other farm work. Cotton gloves are useful, provided the spray material does not soak through; then any glove becomes worse than useless.

Rubber or oilskin coats are sometimes worn in cold weather or to protect the clothing from the paint-like stains of spray material. But too much protective armor interferes with the free movement of the nozzle-man, and in hot weather is obviously impractical, so coats are the least necessary form of protection.

Anyone who has sprayed or dusted in the orchard day after day will probably agree that eye protectors may be a very useful accessory in such work. Ordinary spectacles will offer considerable protection from drifting spray, but are not so satisfactory for dusting work. Goggles, which completely encase the eyes are the only sure protection against dust materials, but because the glasses steam up so constantly in hot weather, they are not used very much in spraying work.

When students or others not accustomed to the work plan to apply a dormant spray of lime sulphur they may avoid some of the discomforts of burns by applying vaseline liberally to their faces, and also to their hands, if gloves are not worn.

CHAPTER V

DUSTING OUTFITS

THE improvement of dusting equipment has been nearly as rapid as the development of new and better dusts, so we find at the present time a variety of equipment intended for the limited needs of the city gardener with a few plants in the back yard and

also for the exacting requirements of the orchardist, the market gardener, and the cotton grower.



FIG. 64.—Dust is Shaken from the Hopper by the Operator through a Sieve in the Flaring Base.

Dusting equipment may be classified according to the method of operation into hand dusters and power equipment. The simplest type of hand duster is the shaker which is nothing more than a metal container with a perforated bottom through which the dust sifts out upon the plant when the container is shaken. Crude and primitive imitations of this type are found in the burlap and cheesecloth bags which are sometimes used.

The bellows principle has been applied to another type of hand duster. A small hopper is provided near the outlet for the dust, and as it drops slowly from the hopper through a small opening in the air passage it is blown out by the current of air as a cloud of dust. The bellows are operated in the same manner as the type which adorns the old-fashioned fireplace. An outfit of larger capacity has been introduced, which is carried on the

operator's back. One hand is used to operate the bellows' lever while the other directs the discharge pipe. The hopper is of large size and has an improved dust-feeding device. This outfit is winning favor because of its efficiency, and it is especially valuable when crops are planted in hills some distance apart, as

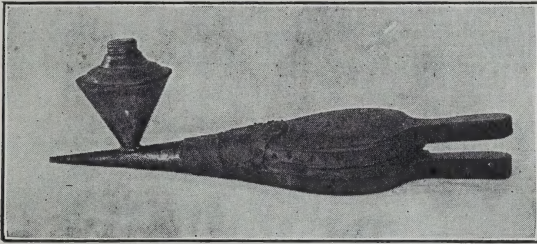


FIG. 65.—Small Bellows Type of Duster.

in the case of cantaloupes, tomatoes, etc. Young trees may also be dusted more easily because of the flexible discharge tube than would be possible with the rigid pipe on dusters operated by cranks.

A third kind of hand duster may be called the plunger type.

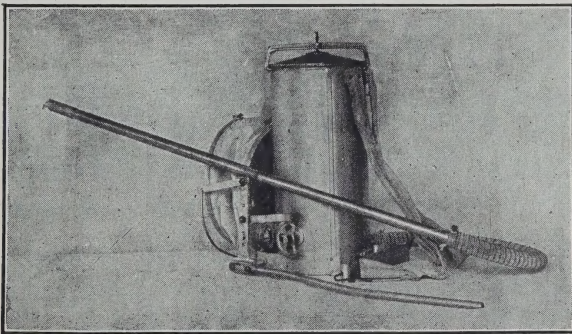


FIG. 66.—A Bellows Type of Hand Duster of Good Capacity. It may be Used on Small Trees.

It is useful only for small scale operations since it does not have large capacity. It consists of an air pump and hopper for holding the dust. The pump is double-acting and generates an almost continuous current of air and a corresponding flow of dust. Those who use it find that the air pump requires good care to function

properly and that it is tiresome to operate. Both the bellows and plunger types are frequently used in greenhouses.

The most commonly used and one of the most efficient hand outfits is of fan-blower design. It has good capacity, is easy to operate, and produces a steady flow of dust. This type is also known as a crank duster, due to its method of operation. Because it is a hand outfit, it is constructed of light materials, and its rapidly moving parts are subject to wear and frequent repair. Because of this the working parts should be readily accessible,



FIG. 67.—The Duster Illustrated in Fig. 66 in Operation.

and, unfortunately, this is not always true of crank dusters. The hopper is located directly over the air chamber and revolving brushes feed the mixture into it. As the capacity of a dusting outfit increases, the need for a good feeding device becomes greater, for some dusts pack or cake and will not feed readily without a proper feed adjustment. On some makes there is also a provision to vary the amount of dust which enters the air chamber and this is called a regulating valve. The fan generates a continuous current of air which keeps the dust flowing steadily through the discharge pipe. One hand is used to turn the crank for the blower while the other directs the application of dust as it

flows out of discharge pipe. Perhaps the fan-blower hand duster is used more in cotton fields than elsewhere and here its capacity rating is about eight acres for the season.

Traction Dusters. This type is presumably designed as intermediate in cost and capacity between the most efficient hand outfit and the gas-engine machine. Not a great deal is known at the present time regarding the practical value of a traction duster.

The fan blower is used for both the traction and gas-engine types to force the dust upon the plant. A dust hopper of fairly large capacity, a feeding device, an air chamber, discharge tubes, and nozzles make up the balance of the equipment for both. The fan is operated from the two wheels on which the traction

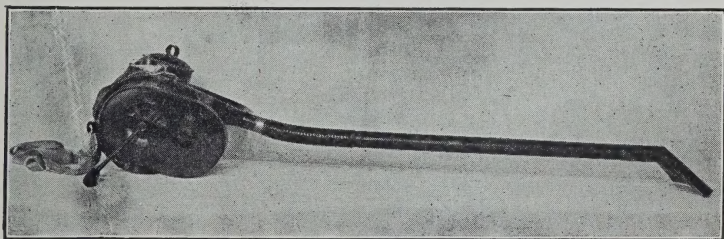


FIG. 68.—An Efficient Hand Duster Operated by a Blower Fan.

machine is mounted, gears being used to transmit the power to the fan. When an engine furnishes the power a belt operates the fan.

There are two general methods of discharging dust. Where the dust is fed into an air chamber, and then forced out by a blast of air, the hopper is always located above the air chamber. In other makes the dust is fed directly into the fan or blower, and in such cases the hopper is located above and to one side of the fan. The advantages claimed for the latter method are that it breaks up lumps and pulverizes the dust. Because there is no air pressure to cause the dust to back up, the hopper may be opened and refilled while the machine is operating.

Experimental work is now being carried on to compare the effectiveness of traction dusters with traction and power sprayers on potatoes and other low-growing crops. The observations made thus far indicate that traction outfits have a greater tendency to clog¹ than engine-driven machines. If a team slows

¹ Progress Report Potato Dusting Experiments, 1921, Dept. of Plant Pathology, Cornell University.

down, the fan does also, which results in a congestion of dust in the tubes. Although traction machines are lighter in weight the actual draft is no less because the power is generated through the wheels. Both outfits are unsatisfactory when operated on steep slopes because of the side slippage, so at present only hand dusters may be used satisfactorily for these conditions.

Wheel injury to plants is sufficient to decrease the yield noticeably, and manufacturers of dusting and spraying machinery

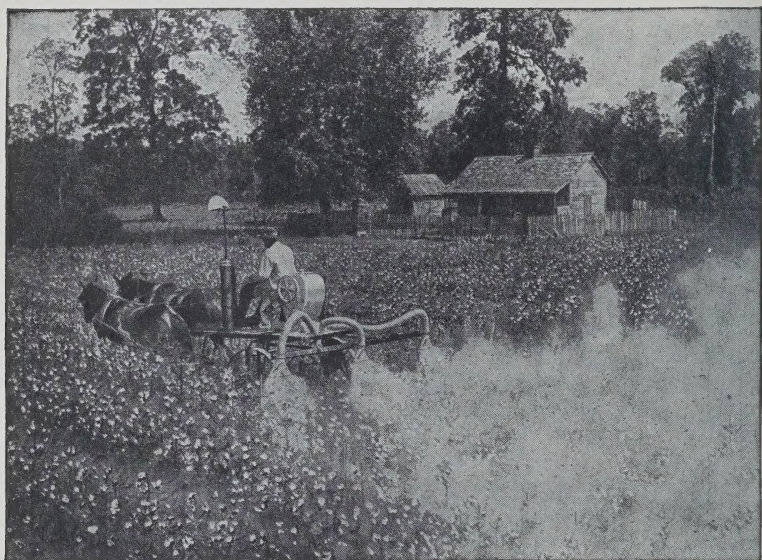


FIG. 69.—Cotton Duster in Operation. Note the Acetylene Light for Night Operation.

should carefully consider ways of overcoming it. The grower can partly reduce the injury by planting in straight rows.

Greater emphasis is also being placed on dispersing dusts forcefully, and this will require greater power than the lighter outfits now generate. The delivery tubes are often faulty and the control levers need to be improved. Most of these faults are of a mechanical nature, and although much credit is due the manufacturers for the rapid improvement of dusting equipment, further work along this line is most essential.

Traction dusters have been used for a number of years in dust-

ing cotton for control of the boll weevil. For this work machines have been made of one-wheel design which may be drawn by one mule. Two-wheeled, two-mule machines are also in use. The former may cover from 15 to 20 acres in one night's operation, while the two-wheeled machines will cover from 25 to 30 acres. The former should not be allotted more than 60 acres for the season, the latter not more than 100.

Power Dusters. For large-scale operations a power duster is easily the most efficient outfit on the market. It will cover more rows of low-growing crops and is the only type suited to the more exacting requirements in the orchard. Its general construction has been mentioned under Traction Outfits. By means of a device for disengaging the belt, power may be turned off from the fan

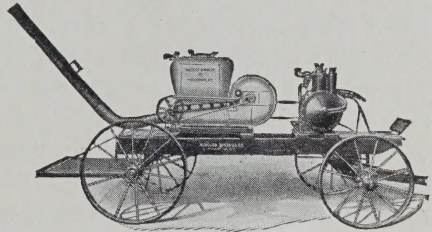


FIG. 70.—Orchard Power Duster.

while the engine continues to operate. This is convenient, especially in orchard work, for the outfit must necessarily move on to the next tree, although a continuous flow of dust is not essential or economical in the peach orchard or with young trees.

A power outfit equipped for orchard dusting has a sectional discharge pipe connected to the blower by a flexible tube. This enables the grower to move the pipe about freely so as to cover all portions of the tree. This discharge pipe is made in sections, the total length depending on the size of the tube, the horsepower of the engine, and the projecting power of the fan.

Only a short time ago standard power dusters were rated in power as equivalent to 6 to 8 inches of water pressure at normal speed. By speeding them up as high as 10 inches could be secured. More recently machines developing 22 inches of water pressure at 3500 revolutions per minute, have been developed, and the present tendency is toward the larger more powerful machine.

In power dusters the hopper, air chamber, and blower are usually constructed of sheet iron, but in the more expensive outfits, cast aluminum is used because it is exceptionally durable, and at the same time lighter in weight.

If the greatest good is to result from dusting, an outfit should be selected only after careful consideration has been given to the requirements to be placed upon it. When the dust is not to be projected very far, probably a traction or a power duster with a 2- or 3-horsepower engine is suitable, but for dusting in mature apple orchards it is doubtful whether an outfit with less than 5 horsepower will prove satisfactory.

The need for studying requirements may best be shown with vegetable crops. A description of an outfit intended for this purpose follows:¹ 2 $\frac{1}{4}$ -horsepower engine, blower fan revolving about 2500 revolutions per minute, mounted on two 4-foot wheels adjustable in spread from 4 feet 8 inches to 8 feet. Delivery tubes convey dust from the hopper through reinforced rubber hose and flexible metallic tubes to eight nozzles or spreaders having wide flaring mouths. The positions of these nozzles may be adjusted to suit the size of the plants and the width of the rows, and recently an open-backed nozzle with a guard on the lower side is being used to overcome the clogging caused by dew. Extension arms on which the nozzles are attached fold up to allow the machine to pass through gateways.

When nicotine dust is used for aphid control it is essential that the insects are surrounded by a cloud of dust, for the nicotine vapor given off is the effective killing agent. Since these insects occur on the under surfaces of the leaves the outlets must be directed upon each row of plants in sufficient number to force the dust under and among the leaves from various angles and directions.

For tall-growing crops like eggplants, potatoes, and tomatoes 4 nozzles are used to the row, 1 at either side of the plants, and suspended slightly above them with the nozzles angled downward. The other 2 are arranged nearer the base of the plants, the outlets pointing inward and slightly upward. This plan is considered essential for both insect and fungous control.

In aphid control on cantaloupes and cucumbers the outlets are trained to pass as close to the plants as possible, pointing forward, backward, and at angles to these directions so as to force the dust to both surfaces of the plant.

An effective method for dusting spinach with its recumbent

¹ Zimmerley, Geise, and Willey, Dusting Vegetable Crops, Virginia Truck Exp. Sta. Buls. 35 and 36,

leaves involves the removal of the flaring outlets and substituting 6-inch lengths of 1-inch rubber hose which readily slip over the end of the metal tubes. The tubes are trained low between the rows of spinach, and attached about midway to the boom is a 1-inch iron pipe, the weight of which holds the rubber nozzles close to the ground in spite of the varying height and contour of the land. The six inside tubes are grouped in pairs, the outlets pointing toward each row. The remaining tubes, one on either side of the pairs, have nozzles pointing inward, thus completing the dust application to four rows.

A canvas of light weight ¹ 5 feet wide and about 6 feet long may be attached to the iron pipe previously mentioned, and allowed to drag on the rows behind the outfit to prevent the interference of air currents in the efficient delivery of the dust. The ends of the canvas which drag between the rows should be weighted.

¹ Zimmerley, Geise, and Willey, Dusting Vegetable Crops, Virginia Truck Exp. Sta. Buls. 35 and 36.

CHAPTER VI

DUSTING AS A MEANS OF CONTROLLING INSECT AND FUNGOUS PESTS

IN this discussion the term dusting rather than "dust-spraying" will designate the practice of applying dust for insect and plant-disease control. The word spraying as used in this manual will refer to the application of insecticides and fungicides with water as a carrier.

History of Dusting. The use of sulphur as a dust probably dates back farther than any other fungicides now being used (1846),¹ so that its connection with disease control is neither recent nor accidental. Interest in dusts for the control of pests in orchards, vineyards, and gardens has passed through two definite periods of revival. The first occurred between 1900 and 1908. The second began in 1912 and has continued with sustained interest until the present time.

The first movement to substitute dusting for spraying in the apple orchard began in Missouri about 1900. The hilly orchard land and the scarcity of water seemed to favor dusting. The movement thus started led other states to undertake investigations about 1902. From 1905 to 1908 experiments were reported from Delaware, Michigan, Illinois, Washington, Arkansas, Missouri, Oregon and New York.

The results in Missouri were not very satisfactory. More extensive tests at Illinois showed that dusting was ineffective in checking fungi and less efficient than liquid insecticides for the control of insects. More favorable results were reported from Michigan, New York, and Delaware, yet the practice of dusting and further investigational work was practically abandoned about 1908.

Recently investigators have accounted for these early failures as follows: First, the dry Bordeaux and Paris green used were too heavy and not ground sufficiently fine. Second, not enough was

¹ E. Bourcart, *Insecticides, Fungicides, and Weed Killers*, p. 44, 1913.

then known regarding the life history of many important fungi and insects, hence the applications were not always made at the proper time. Third, the value of applying dust when the atmosphere was calm, as in the early morning hours, was not fully appreciated.

In 1908 Cordley of Oregon discovered the value of lime-sulphur solution as a control for apple scab, and following that discovery lime-sulphur was widely adopted as a substitute for Bordeaux in the control of orchard diseases. About this time, also, arsenate of lead was largely replacing Paris green as an arsenical.

In 1911 dusting investigations were revived at Cornell. Reasons for resuming the work were given as follows:

First, with the increasing cost of labor and the necessity for getting fungicides on the affected parts of fruit trees in a limited time, some quick method seemed desirable.

Second, the end product resulting from lime-sulphur sprayed on the tree is sulphur, hence why not apply it as a dust?

Third, dusting had proven successful in the control of powdery mildew of the grape and hop mildew.

Experiments using sulphur and arsenate of lead as dusts compared with these materials applied in liquid form were carried on at Cornell during the years 1912 to 1915. The average results obtained for the four years as reported in Bul. 354 were as follows:

Perfect apples	3.3 per cent in favor of dust.
Scab control	1.7 per cent in favor of spray.
Worm control	1.9 per cent in favor of dust.

These favorable results from the use of sulphur and arsenate of lead brought about a resumption of experimental work in various parts of the continent. Further results with these and other dusts are considered under the discussion of materials.

Advantages of Dusting over Spraying. Those who are most enthusiastic about the practice of dusting claim that tree fruits, potatoes, vegetables, and small fruits can be dusted in one-fifth of the time required to spray them. Covering 30 acres of vegetables in a day with a power duster, 35 acres of small fruits, and 40 acres of orchard are the frequent achievements to which these advocates point. Comparing this method with spraying they consider it full five times faster. Although the daily average of

work might not show so great a contrast in the acreage covered, yet dusting, under all conditions, is much more rapid than spraying.

The time during which certain pests may be efficiently controlled is very brief (sometimes only 5 or 6 days), and during these critical periods the spraying problem is one of having a sufficient number of reliable men and outfits to accomplish the work within the limited time. Under such conditions the number of men and teams needed for dusting would be 25 per cent or less of the spraying requirements. Other advantages, such as a much lighter outfit, lower initial cost, and operating expense are freely accorded to the dusting machine, and if the all-round effectiveness of dusting were equal to spraying and the total costs were no greater this practice would quickly replace the more common custom of spraying. But along with these advantages we must consider the efficiency and cost of dusts in the control of insects and diseases. A survey of results shows no superiority over spray mixtures, in fact dusts are much less generally useful in the orchard, and at their present stage of efficiency they cannot replace, but merely supplement spraying. Dusts which largely replace spraying on other crops are considered under the discussion of materials. The reader should bear in mind that dusts and the machinery with which they are applied are still in the developmental stage.

General Qualifications for Dusting Materials. The fineness of the dust used in pest control is an all-important consideration. The best kinds now available are guaranteed by the manufacturers to pass 50 to 75 per cent through a sieve having 300 meshes to the square inch. A great deal of time and money has been devoted to the development of fineness in these materials, and one copper dust has just appeared, 98 per cent of which will pass a 325-mesh screen. Lightness is also an important factor, since dust depends on the air as a carrier.

Whether the dust will adhere as tenaciously to plants as will spray mixtures has been a matter of debate. The dust is so fine that under favorable conditions it seems to adhere to the pubescent surfaces of leaves and to most other portions of the plant fully as well as liquids. Under adverse weather conditions its sticking qualities are more variable than for sprays and in regions where the rainfall is heavy the dust is largely removed, while the spray will stick if allowed a short time to dry.

Materials Used as Dusts.—Sulphur. The favorable results obtained from the use of sulphur in the Cornell experiments has made it the leading dust fungicide at the present time. The degree of fineness required for dusting is many times greater than in the material used to make self-boiled lime sulphur. The cost is also greater than for materials used in spraying.

More than one form of this dust fungicide has been used. At an earlier date flowers of sulphur, which is the finest grade of sublimed sulphur, was about the only satisfactory kind, but now very finely ground forms are greatly preferred for dusting. These are finer than the best sublimed grades and cost no more. When used alone these forms have a tendency to cake or form small lumps, choking up the feeding device on the machine. This fault may be overcome by diluting with a filler, which not only improves the flow of dust, but reduces the cost.

When this fungicide is used in combination with other materials it comprises from 50 to 90 per cent of the mixture, depending on the seriousness of the disease.

The value of this material as a dust fungicide in orchard work has been compared with lime sulphur and lead arsenate applied as a spray in a number of different states.

The following brief and excellent summary is quoted here:¹

"The published results from New York, Michigan, Illinois, Nova Scotia, and Ontario indicate an efficiency equal to that of lime sulphur and lead arsenate for the control of apple scab and codling moth. Virginia and West Virginia workers report satisfactory control of codling moth, but say it is unsatisfactory for black rot, bitter rot, rust, and scab of apples, and in Virginia for brown rot of peaches. Peach-dusting experiments in Georgia and West Virginia indicate an efficiency against scab and curculio equal to that of the sulphur spray and slightly less control for brown rot. Results in Maryland are less favorable to control of orchard fungi by dusting than by spraying. Whether it is better to dust than to spray, and just what diseases can be better controlled by dusting are questions that have by no means been fully answered. Dusting has many opponents as well as advocates among both scientists and practical growers."

¹ Holland, Bourne, and Anderson, Mass. Bul. 201, Insecticides and Fungicides.

Apple diseases not controlled effectively or economically at the present time by sulphur dust include anthracnose, apple blotch, black rot, bitter rot, mildew, New Hampshire fruit spot, and sooty blotch. Anthracnose and mildew are troublesome in the Northwest; apple blotch and bitter rot in the southern portion of the apple belt. The limitations of sulphur for other crops have not been so definitely worked out.

Copper-lime Dust. This is a comparatively new fungicide used first in an experimental way in 1918 by Sanders and Kelsall in Nova Scotia. The latest formula available includes 12 pounds of dehydrated copper sulphate, 10 pounds of calcium arsenate, and 78 pounds of hydrated lime. This mixture is finer than sulphur lead dust and it covers more tree area. The 12-10-78 mixture gave fully as good control of apple scab as Bordeaux mixture and much better control than sulphur dust. A two-year comparison of copper-lime dust and Bordeaux mixture for the control of late blight on potatoes showed that these two mixtures were equally effective. Formulæ for copper-lime dust change so frequently that for best results the most recent literature should be sought.

In New York State a comparison of copper-lime dust with 6-6-50 Bordeaux spray mixture¹ showed the latter gave greater protection against such insect injuries as tip burn, hopper-burn, and those caused by flea beetles. Weather conditions were not favorable for the development of late blight during the season, so it was not possible to make a comparison for this disease. The spray was applied with only two nozzles to the row at a maximum rate of 100 gallons to the acre. Since the most recent and approved practice calls for three nozzles to the row, 200 gallons to the acre for mature plants, and a pressure of 200 pounds, further investigations which include this practice as a basis will be of great interest. Similar improved practices in dusting vegetable crops include greater power at the blower, dragging a sheet behind the duster to confine the fumes, and the use of larger, better designed nozzles.

Arsenate of Lead. This is the most useful dust insecticide except in the control of boll weevil, and if chewing insects were the only serious problem in pest control, this arsenical in dust

¹ Progress report on Dusting Potatoes in 1921, Dept. of Plant Pathology Cornell University.

form would more often replace spray mixtures. It is used on various trees and small fruits as well as truck crops. Unfortunately the enemies other than chewing insects are not so readily controlled, and in certain regions even these insects are controlled better by spraying. As high as 20 parts in 100 of dust mixtures have in rare instances been arsenate of lead. Fifteen per cent of the formula has more frequently been tried in an effort to obtain the highest possible percentage of fruit free from insect injury, but at this strength the dust is too expensive. The formula now used in the majority of cases is of 10 per cent strength.

A. L. Quaintance,¹ Entomologist in Charge of Fruit Insect Investigations, Federal Bureau of Entomology, summarizes the results obtained in dusting and spraying apples in five different sections of the country as follows:

"In regions where the codling moth is not especially severe, as in the New England states and other more northern states, dusting controls this insect practically as well as spraying. In regions where the codling moth is more abundant, due to a larger second brood, or to subsequent broods of larvæ, as in Maryland, Virginia, Illinois, and the Ozarks, dusting is not a satisfactory control. In such arid regions as the Grand Valley, Col., where the codling moth is very prolific and injurious, dusting is notably less effective than spraying." The regions in which these experiments were conducted are Benton Harbor, Mich.; Winchester, Va.; Bentonville, Ark.; Wallingford, Conn.; and Grand Junction, Col.

Dusting with arsenate of lead for the control of plum curculio on peaches has not given conclusive results to date in all sections of the country. In Mississippi and Georgia dusting has been about as effective as spraying, during periods where curculio, scab, and brown rot are in average abundance and average weather conditions prevail.

Calcium Arsenate. Calcium arsenate is used far more on the cotton crop in the control of boll weevil than elsewhere, and although this is not a horticultural crop, a fair statement on dusting must recognize the success made where this material has been applied in dust form. Calcium arsenate is more effective than lead arsenate in the control of cotton boll weevil. In 1919,

¹ Journal of Econ. Entomology, Vol. 14, No. 2, p. 220, 1921.

3,000,000 pounds of poison were used for this pest and the work of the U. S. Department of Agriculture¹ in this connection involved 75,000 acres.

Gains of 200 to 400 pounds of seed cotton per acre frequently result from effective dusting. However, the amount of weevil injury varies considerably, and dust should not be applied if the cost of labor and calcium arsenate plus the depreciation of dusting machines exceeds the market price of 100 pounds of seed cotton. It costs just as much to dust an acre of cotton yielding only a quarter of a bale as one yielding a bale. This reservation which suggests dusting for boll weevil only when the cost is below a certain limit presents a situation quite different than the one confronting the fruit grower who must dust or spray according to a local schedule in order to make it worth while to continue in the business. Even in years when frost wipes out the entire crop some measures may need to be adopted to check the insect and fungous enemies which would otherwise be recruiting their strength for an unusually destructive attack upon the next crop.

Five to 7 pounds of calcium arsenate are used per acre, and since dusting is much more effective when the air is calm it is usually applied at night. A special density machine has been devised by the Federal Department of Agriculture. The density for calcium arsenate should be not less than 80 nor more than 100 inches to the pound. Other purchase specifications are that the poison should contain not less than 40 per cent total arsenic pentoxide and not more than .75 per cent water-soluble arsenic pentoxide.

Calcium arsenate is used to a limited extent on potatoes in the control of the Colorado potato beetle, and where this is the only pest requiring control it is successful. But in certain regions the control of the leaf hopper is more important, and in other regions the control of diseases is necessary, and these factors limit the use of dusts, because they have not been so thoroughly tested for all kinds of pests as have the mixtures used with water as a carrier.

When calcium arsenate is applied to plants for the control of cucumber beetle or to potatoes for the potato bug a common mixture is 1 pound of calcium arsenate to 20 pounds of filler.

Dusting fruit trees or small fruits with calcium arsenate has

¹ U. S. D. A. Yearbook, 1920, Killing Boll Weevils with Poison Dust.

been tested only in a very limited way. When combined with copper sulphate as a combination dust, calcium arsenate has been reported as causing less injury to fruit trees, such as apple, cherry, pear and plum, than when combined with the amount of lime usually recommended.

Nicotine Sulphate Dust. Within recent years nicotine applied in dust form has attracted attention as an efficient insecticide against walnut, melon, currant and cabbage aphids, onion thrips, and other insects. Investigations have shown that when the labor of application is included it costs more than the liquid form and, as with other dusts, plants may be covered faster. When ready for application the dust contains from $\frac{1}{2}$ to 3 per cent of nicotine, the variation resulting from an attempt to find the cheapest effective nicotine content. The amount was also varied in some instances because insects differ in degree of resistance to the toxic effect of nicotine. The earliest successful results in preparing this material as a dust were obtained by impregnating finely pulverized kaolin with a 2 per cent content of standard nicotine sulphate. At a later time lime was added in the proportions of 1 part to 3 parts of kaolin and then it was found that the fineness of kaolin made it desirable to increase its proportions when trees were to be dusted and to decrease the kaolin to make the dust heavier when treating low-growing crops, such as cabbage and melons. Still later lime was used almost exclusively as a carrier, since it liberated the volatile nicotine more readily.

Yet the rate at which it releases nicotine is not considered satisfactory, as it is much slower than the rate of delivery in liquids, and rain occurring within 72 hours may seriously interfere with the efficiency of the dust. Since clay was known to absorb nicotine, experiments were conducted by Dr. T. J. Headlee¹ of the New Jersey Experiment Station to determine the readiness with which clays would give off nicotine. Neither the pure clays nor those mixed with lime (calcium oxide or calcium hydroxide) liberated nicotine as quickly as when lime was the only carrier used. Other investigators have found that some clays give off nicotine even less readily than those tested in New Jersey, so the hunt is still on to find a carrier which will liberate nicotine

¹ Headlee, T. J., and Rudolfs, W., Some Further Experience with Contact Dusts, *Journal of Economic Ent.*, Vol. 15, No. 1, p. 75, 1922.

more rapidly than lime, thereby reducing the waste of nicotine and the present cost of the dust.

Dust carriers (including clay) which are impregnated with 2 per cent nicotine were as effective as nicotine applied with water as a carrier. The cost is greater for dusting and its general and successful use in the future lies in reducing its cost.

The latest known practice is to mix the nicotine with some absorbent, inert base like infusorial earth. This base is then mixed in a tight container with the best liberator now available, finely ground calcium oxide. Free nicotine volatilizes more quickly than nicotine sulphate, and the less the amount of moisture in the dust, the quicker will the nicotine gas be liberated. Investigators also believe that the effective killing takes place within a minute after the dust is applied. Trebling the volatility of the earlier dusts, and confining the fumes for extra seconds by dragging a sheet after the duster, have produced a remarkable increase in its killing efficiency. It should contain not less than 3 per cent nicotine, according to recent findings. When the cost for dusting with this material can be reduced sufficiently to compete with spray mixtures, its use will doubtless become general.

Lead arsenate, when added to a combination dust, reduces the volatility of the nicotine a little, and copper in any form reduces it a great deal. Copper and nicotine should never be mixed in the same formula.

Perhaps the most comprehensive dusting work reported thus far is that of Mr. P. J. Parrott¹ of the Geneva (N. Y.) Experiment Station, whose observations were made on sucking insects. He tested the killing power of dusts varying in nicotine content from .5 per cent to 2 per cent and studied the accessory factors to determine their importance in effective dusting operations. His conclusions were that nicotine dusts were toxic to apple aphids, red bug, leafhoppers of the apple, the currant aphid, and four-lined plant bug. Dusts containing .5 per cent of nicotine were fatal to apple and currant aphid and red bug. This strength made the nymphs of the four-lined plant bug temporarily inactive, but most of them recovered later. Two per cent mixtures were fatal, but expensive.

¹ Parrott, P. J., Control of Sucking Insects with Dust Mixtures, *Journal of Econ. Ent.*, Vol. 14, No. 2, p. 206, 1922.

Mixtures containing .5 per cent nicotine killed only a small percentage of hibernating adults of pear psylla, and preparations containing 1 per cent were less effective than spraying mixtures composed of nicotine sulphate and soap in the usual proportions. Even when 2 per cent mixtures were used the nymphs of pear psylla displayed considerable resistance.

Mixtures containing less than 2 per cent nicotine gave very poor control of the potato aphid.

Dust dosages of the various strengths already mentioned were tried as controls for apple red bug.¹ "Considering the needs of average growers and prevailing prices for material and labor, the apple red bugs can be more efficiently and economically controlled by spraying than by dusting," was the conclusion reached.

Comparative tests of dusts and liquids in controlling the cabbage aphid showed that hydrated lime containing 2 per cent nicotine gave satisfactory results most economically. The increase in yield of cabbage varied from 4 to 6 tons according to the kind of treatment. When 15 pounds of powdered lead arsenate are combined with 5 pounds nicotine sulphate, Professor Parrott states that we have a very promising method of treatment which appeals strongly to the leading cabbage growers in the vicinity of Geneva.

Professor Parrott observed further that "air currents, denseness of tree growth, low temperatures, and exudates of insects, such as wax and honeydew, exerted a greater adverse influence on the efficiency of dusting preparations than on that of spraying mixtures. These results suggest that while certain principles of procedure apply equally well to both systems of orchard treatment, the field technique required for effective dusting differs in important particulars from standard spraying practices. In its present stage of development dusting displays defects both as to methods of application and machinery which will probably be overcome by the corrective processes of experience. A study of present dusting methods shows also that a distinction should be made between obvious limitations of dusting materials and machinery, and failures which arise from attempting to dust under conditions that are unfavorable for effective work. In these experiments,

¹ Parrott, Glasgow, and MacLeod, Geneva Bul. 490, Control of Apple Red Bugs by Dusting.

operations which proved promising when no breeze was stirring and when the trees had open tops would not infrequently yield quite different results when strong air currents prevailed and the tree growth was dense. The inefficiency of dusting was most marked with the pear psylla and woolly aphis, as the honeydew and waxy secretions of these insects were repellent to the materials. It was also noted that during periods of low temperature dusting was less effective than when high temperatures prevailed." The greater effectiveness resulting from dusting at higher temperatures was probably due to the greater rate of volatility of the nicotine.

Professor R. E. Smith of the University of California has developed a nicotine sulphate dust for the control of walnut aphis which he has named "nicodust." This name has come into such general use that it now designates any dry material treated with a nicotine extract and the term has found its way into many published articles. Several large firms manufacturing insecticides are offering nicodust for sale, and investigations are under way to determine its most effective use in combination with sulphur and other fungicides, as well as the arsenic compounds. The formulas now recommended vary widely with different crops and may change with further investigations. For specific strengths the most recent literature should serve as a guide.

Fillers. Dusts are rarely applied without the addition of a filler to reduce the concentration and cost of the dust. Fillers must have the properties of lightness, fineness, and cheapness to an unusual degree if they are to be suitable. Fillers commonly used are hydrated lime, kaolin, and gypsum or land plaster. There seems to be only one satisfactory filler for copper dusts at the present time and that is dolomitic hydrated lime. The fungicidal value of dusting sulphur depends on its slow oxidation in the form of sulphur dioxide. This is neutralized when lime is used as a filler, according to recent findings. For this reason, a substitute for alkaline fillers, such as lime, may soon be sought for use with dusting sulphur.

Lime is the lightest of these fillers, having a specific gravity of 2. It is the most readily available of the three and the cheapest, while kaolin is the most expensive.

Land plaster is not easy to obtain in some sections of the country and before it is suitable it must be finely ground because

of its granular tendency. It is a chemical deposit from the evaporation of inland lakes or other large bodies of water. Chemically it is a hydrated form of calcium sulphate. The pure material is white in color, but due to impurities it is sometimes gray, red, or brown. Its specific gravity is 2.3.

Kaolin is a deposit resulting from the decomposition of feldspar and aluminium rock. It is the principal mineral of clay and is known chemically as hydrated aluminium silicate. Most of the kaolin used as filler in dusting is impure and brown or gray in color. Its specific gravity is 2.6.

Abbreviations for Dusting Formulas. For the efficiency of the work it is often necessary to combine a fungicide, stomach poison, and contact insecticide, and when so mixed a series of numbers are commonly used to designate the proportions. In spray mixtures 4-4-50 designates standard Bordeaux mixture. Similar formulas exist for dusts, and in order to avoid confusion the order in which these dusts are designated has been fairly well standardized. The abbreviated way of saying 90 parts sulphur and 10 parts of arsenate of lead is 90-10. Most manufacturers follow the plan of mentioning the fungicide (sulphur or copper sulphate) first and the stomach poison (lead or calcium arsenate) second. If a contact insecticide is included this item comes third in the series (nicotine sulphate dust) and the filler or spreader used with the mixture is combined with the nicotine in the formula. For example, a combination copper arsenate nicotine dust designated as 10-10-80 includes 10 parts copper sulphate, 10 of lead arsenate, 55 of hydrated lime, 20 parts inert filler and 2 per cent of nicotine. The last ingredient is made up from a concentrated nicotine sulphate (40 per cent nicotine solution) and the carrier or filler is impregnated with it by means of applying the solution under pressure with the nozzle.

When a contact insecticide is not included in the mixture the third number in the formula designates the proportion of filler used.

Appropriate trade names are also given to dust combinations and these names suggest the kinds of ingredients, while the numerical formulas indicate the proportions.

Mixing of Materials. Some of the dusts just described may be bought separately and mixed at home at some saving in cost, but to obtain a reliable mixture a machine for mixing

it is necessary. One which is operated by hand has sufficient capacity for the average orchardist, but a growers' association would need a large mixer operated by a gasoline engine. Of the fruit growers who use dust, comparatively few practice home mixing, for they prefer to buy the materials ready mixed. It is not yet possible to make a good nicotine dust at the farm, nor is it advisable to attempt to make green copper dust.

Dusting and Spraying Costs Compared. It is extremely difficult to summarize relative costs of dusting and spraying because they will vary greatly in different seasons and in different sections of the country. Experimental work as a general rule is more expensive than commercial work of the same sort, yet the costs from experiments are more often available. No attempt will be made here to secure average costs nor to consider any comparison except in the mature apple orchard.

In 1914 when prices were normal the cost of sulphur was 5 cents per pound. In 1919 the price had increased to 11 cents. In 1920 and 1921 the price was beginning to return to normal. During these two years the comparative costs for spraying and dusting in an experimental plot carried on by the experiment station of Purdue University were as follows:

1920

Cost per tree per application.....	Spraying, 9	cents
Cost per tree per application.....	Dusting, 19	cents

1921

Total cost per tree.....	Spraying, 6 applications,	
	44.2 cents	
Total cost per tree.....	Dusting, 6 applications,	\$1.07
Cost per tree per application.....	Spraying, 7.3 cents	
Cost per tree per application.....	Dusting, 17.8 cents	

The proportionate cost of the dust in relation to the total cost of the work has remained the same throughout the period from 1914 to 1921, namely, 95 per cent. Present costs for both spraying and dusting are less than for the years 1920 and 1921, owing to the reduced price of labor and materials.

Applying Dust. When dust is substituted for spraying the number of applications and the time when they are applied correspond very closely to the spray schedule.

Where the trees are small, as in a commercial peach orchard, thorough dusting may be done from one side of the tree, and two rows may be dusted at a time as the outfit passes down between them. With large apple trees, however, it is necessary to dust the tree from opposite sides in order to insure thorough work. One authority suggests that 2 pounds of dust will cover as much tree area as 10 gallons of spray mixture. In some experimental work as high as 3 to 3½ pounds of dust have been applied per application, so that the amount of dust used will vary just as widely as the spray mixture. The height to which dust can be thrown and its distribution as a fine covering on the tree depends largely on having a powerful blower and sufficient horsepower. With large apple trees a 5-horsepower duster is considered highly desirable. Outfits of good capacity may be kept moving along the row and yet a sufficient amount of dust will be applied in passing. Trees may be too heavily dusted in an attempt to apply a heavy visible coating. Leaf and fruit injury have been reported on peaches¹ where the dust application has been excessive.

Even a mild breeze may prevent the dust from settling evenly over the plant surface, so it is highly desirable to apply dust when the air is comparatively quiet. This has led to the common practice of applying dust at daybreak, and in certain instances where the work was pressing the outfits have been equipped with powerful headlights so that dusting might continue throughout the night if necessary. Dusting at other times is subject to the whims of the wind, and when night labor is hard to obtain or where the rainfall is excessive this method will not prove practical. The theory that dust should be applied when the plants are wet with rain or dew is not practical. When the plant is dry the dust will settle more uniformly over the entire surface and will find its way among the tiny hairs to better advantage than the usual spray applications. In the presence of water, dust tends to collect in masses at the edges or centers of the drops. Furthermore, when sulphur² is used as a dust ingredient, it becomes insoluble in the presence of water, and so cannot act fungicidally in the way copper salts do.

¹ West Virginia Bul. 167, Orchard Spraying versus Dusting, by N. J. Giddings.

² Doran, W. L., N. H. Technical Bull. 19, Laboratory Studies of the Toxicity of Some Sulphur Fungicides, page 6.

Prevalence of Dusting among Growers. Dusting of cotton is the accepted practice in the South. This practice as a means of pest control for vegetables is slowly increasing, according to the limited information available. A large percentage of apple growers in Nova Scotia have taken up dusting since 1918. The prevalence of this practice in orchard work is definitely known in New York, a state which has held a leading position in dusting work during the last 10 years. Much has been written on the subject, great interest has been created, and the opinion prevails that dust is extensively used in New York orchards. In a paper prepared by Professor C. R. Crosby of the Department of Entomology, Cornell University, and presented before a meeting of Connecticut fruit growers the following facts were offered:

The field specialists in spraying in the principal fruit counties of the state were asked to report on the amount of dusting as compared with spraying in their counties. The percentage of growers using dust except for the delayed dormant in the most important fruit counties varied from $\frac{1}{8}$ of 1 per cent to 5 per cent.

For the state as a whole the weight averages for growers depending entirely on dusting were a little over $\frac{1}{2}$ of 1 per cent. For those dusting except for the delayed dormant application, $1\frac{1}{2}$ per cent. These figures show that the great majority of New York growers have not discarded spraying in favor of dusting.

Professor H. H. Whetzel, in another investigation sent out questionnaires to 225 New York growers who had previously dusted. Out of the 112 reporting, 7 answered no to the question, "Will you dust peaches or apples next season?" In the great majority of instances the replies stated that scab and codling moth were controlled just as well by dusting as by spraying. This is generally true under New York conditions except in the lake regions and in years when scab is unusually severe. In these instances the spray seems to give better results.

Dusting as a practice in Oregon orchards is summed up as follows by LeRoy Childs, Superintendent of the Hood River Experiment Station: "Of our various methods, dust will only control scab and codling moth satisfactorily. Mildew, anthracnose, leaf roller, and the various scale insects are unaffected by dust applications at present known, and must be handled with liquid spray. The use of the duster would then mean duplication of equipment and an overhead charge that the average-sized

orchard cannot stand. For these reasons, the duster has little place in Western orchards at the present time."

The percentage of commercial fruit growers using dust exclusively or as a supplement to spraying in Indiana would be a fraction of 1 per cent, and in Illinois, owners of large acreages who bought dusters in recent years have not given up the spray outfit, but have largely discontinued dusting.

A summary of dusting work in Illinois furnished in June, 1922, by Professor B. S. Pickett, Chief in Pomology at the University of Illinois, follows:

"In 1903, 1904, and 1905 the Department of Horticulture at the University of Illinois conducted extensive experiments comparing the efficiency of dusting with dry Bordeaux and Paris green in comparison with spraying with the standard Bordeaux and Paris green, and in 1915, 1916, and 1917 it made further comparisons of finely ground sulphur and powdered arsenate of lead applied as a dust and as standard sprays of liquid lime sulphur and lead arsenate.

"The earlier experiments conducted by Crandall showed a fair control of codling moth and curculio under dusting and entirely unsatisfactory control of apple scab and other diseases. In Bulletin 106, University of Illinois, Agricultural Experiment Station, page 240, Crandall says, 'The results of the experiments are sufficiently decisive to warrant the conclusion that dust is absolutely not effective as a preventive of injury from prevailing orchard fungi, and that it is considerably less efficient as an insect remedy than is the liquid method of applying arsenates.'

"The experiments with sulphur and lead arsenate have shown results very similar to those obtained by Crandall with dry Bordeaux and Paris green with a little better control of apple scab and apple blotch than that obtained by Crandall. Putting together the results of the experiment station investigations and many observations made throughout the state we conclude that dusting is efficient enough as a means of controlling codling moth, curculio, and foliage-eating insects to warrant its use where only these insects have to be considered. *It does not control San José scale.* It shows a considerable degree of efficiency in controlling apple scab and slightly reducing apple blotch, but its efficiency is so much less than that of liquid sprays that we do not feel warranted in recommending it.

"Dusting appears to us to have a place in very hilly orchards where it is difficult or expensive to haul tanks of liquid or at times when the available water supply has been exhausted or is inaccessible, as dusting is certainly superior to neglect. It also appears to us that dusting might have a proper place in an orchard-spray program as a supplementary or emergency means of controlling insects, being used for late attacks of codling moth which occur at times when fungous diseases give little or no trouble. This would, however, require the purchase of both dusting and spraying machinery and in the case of small orchards would be an added expense which the grower would not care to assume.

"In general, we have found dust consisting of 90 parts of superfine sulphur and 10 parts of lead arsenate the most satisfactory material for orchard work."

Mention has been made of the limitations now placed upon dusting and the details requiring further improvement. In the chapter on dusting equipment, desirable changes in certain parts have also been noted. It is important that current and future field investigations should include records¹ of rainfall and temperature for the duration of the tests. Complete information on the amount of dust used per tree or per acre and the time required for application are very essential. The prevalence and severity of the insects and diseases present in the case of trees, their age, and the stage of host development when applications are made should be matters of careful record. The size, number, and arrangement of plats should be planned to reduce to the lowest degree the probable error in the results obtained.

Men engaged in applying dust materials suffer from the irritating action of the dust upon the eyes, nose, and throat. A dust mask is needed which will prevent these discomforts, yet will allow the men to breathe normally.

SUMMARY

Extensive investigations in dusting have occurred in two periods, the first covering the interval 1900 to 1908, the second from 1912 to the present time. A quicker method of application than spraying, a lighter outfit, an equally effective control at no greater expense were the objects sought.

¹ Crop Protection Digest, Feb., 1922, p. 29.

Dusting is several times as fast as spraying with an efficient orchard outfit, the machine is lighter and cheaper, but the total cost of application is greater, and dusting does not have the general usefulness nor the efficiency of standard spray mixtures. As a practice it can therefore only supplement spraying on most crops at the present time. With the orchard, for example, this involves the purchase of two complete sets of equipment, an overhead not warranted in most orchards.

The fineness of the dust used is an all-important consideration. The present requirement is that it shall pass through a screen having 300 meshes to the inch. Lightness is also essential. Dust is more easily washed off by rains than spray mixture.

Hydrated lime is now the preferred carrier for the active dust ingredients. It is fine, light, easily obtained, and cheap, but its neutralizing power when mixed with sulphur may bring about the substitution of another filler.

Dusting can be successfully done only when the air is comparatively calm. Moist leaves do not afford as even and complete distribution as dry leaves.

Sulphur is the leading dust fungicide. In some states its efficiency has been equal to liquid fungicides for apple scab, in others it was less efficient. Among the diseases of the apple alone, which are not controlled satisfactorily by sulphur dust are, black rot, apple blotch, bitter rot, anthracnose, sooty blotch, mildew, and New Hampshire fruit spot. With other crops its control of diseases varies from nearly equal effectiveness to unsatisfactory control.

Copper-lime dust is a promising new combination. This form of copper has compared fairly well to date with standard Bordeaux spray mixture applied to apple trees, potato and tomato vines.

Arsenate of lead is the leading dust insecticide for tree and small fruits and truck crops. The dust form is effective in the northern states, but not in the southerly arid regions where chewing insects have more broods and are more difficult to control.

Calcium arsenate is used successfully as a dust for cotton boll weevil. It is cheaper and more effective than arsenate of lead, but is not recommended at the present time for the majority of horticultural crops.

Nicotine dusts are effective in the control of sucking insects

if used stronger than when applied with water, but at this strength is too expensive. This is because lime releases nicotine much more slowly than water. A carrier is now sought which has the good qualities of calcium oxide, preferably a finely ground dolomite lime and which will release nicotine more rapidly.

Dusting for San José scale has not proven practical, and this fact alone makes necessary the retention of spraying equipment for plants subject to the attack of this insect.

The prevalence of dusting among fruit growers in the state of New York varies from $\frac{1}{8}$ of 1 per cent to 5 per cent. The average for the state is $\frac{1}{2}$ of 1 per cent. Probably the dusting of fruit is more prevalent in New York than in other portions of the United States. A much larger percentage of apple growers in Nova Scotia are reported as dusting.

Dusting is still in the developmental stage and with continued improvement in materials and equipment may have greater possibilities in the future than at present. Present indications are that the future possibilities for dusting may be somewhat greater for low-growing crops than for tall trees.

CHAPTER VII

MISCELLANIES

SEVERAL matters relating to control measures remain to be considered. They are important, but not equally so; no one of them deserves a chapter, and none of them may properly be inserted in the foregoing chapters. They are not, moreover, closely related, but they seemed worthy of inclusion in the manual.

COST OF SPRAYING

The cost of spraying will vary with the price of materials and equipment and to a lesser degree with the labor wage. The great majority of cost studies in spraying are based on the use of the rod and small disk nozzles. Messrs. Folger and Thomson¹ of the U. S. Department of Agriculture have conducted detailed studies in hundreds of orchards in various parts of the United States. The basis of their work has been a three-man and two-horse crew operating a power-spray outfit. Dusting and the spray gun were not considered.

In a 10-hour day it was found that such a crew would spray from 3 to 5 acres of bearing trees, depending on the size of the trees, the capacity of the outfit, and other factors. The comparative table given below shows a wide variation in the number of gallons of spray applied per day, the average in Yakima and Wenatchee being 1750 gallons, while in western New York the average was only 1100 gallons a day. This remarkable difference in the efficiency of spraying crews in different fruit regions may be partly explained by the fact that western growers utilize the irrigation ditches, and this greatly expedites the reloading of spray tanks.

The table given below affords an interesting comparison, also, in the amount of spray material applied per tree and per acre

¹ Folger and Thomson, Commercial Apple Industry of North America, p. 228.

in various fruit regions. The Hood River grower applies only 3 gallons to a tree as compared with an average of over 6 gallons applied elsewhere. In making this comparison the reader should take into consideration the size and variety of the tree. For instance, the Hood River Newtown with its low head should not require nearly so much spray material as a 40-year-old tree grown in New York. The table seems to indicate that the Wenatchee grower sprays his trees more thoroughly, for he uses nearly as much material (6 gallons) as the New York grower uses on much larger trees (7 gallons).

The conclusions reached by Messrs. Folger and Thomson were that in orchards which are thoroughly sprayed the annual expense will be about \$40 a bearing acre if depreciation of the spray outfit is included.

TABLE VI

SHOWING RATE AND COST OF APPLYING SPRAY MATERIALS IN SIX OF THE LEADING APPLE REGIONS

	Wenatchee	Yakima	Idaho	Hood River	Western Colo.	New York
Acres a day.....	3.4	4.24	3.57	5.47	3.8	4.6
Gals. a day.....	1766	1743	1253	1205	1904	1150
Gals. an acre.....	515	411	379	223	501	250
Gals. a tree.....	6.3	5.3	6.3	3.1	6.8	7
Average no. sprays	3.4	4.98	4.09	5.65	3.7	3.5
Cost of spraying...	\$37.00	\$42.00	\$40.00	\$30.00	\$36.00	\$25.00
Cost of labor.....	20.00	26.00	23.00	18.00	22.00	14.00
Cost of materials..	17.00	16.00	17.00	12.00	14.00	11.00

During the years 1918 to 1921, 976 potato-spraying demonstrations¹ were conducted in 57 counties of Pennsylvania. They showed an average increase of 56.7 bushels per acre, or an increase of 36.7 per cent in yield. The spray outfits used were equipped as nearly as possible to meet the latest requirements in potato work.

Because improvements in machinery for potatoes and other vegetable crops are so recent, cost figures other than the Pennsyl-

¹ Nixon, E. L., and Hodgkiss, H. E., Penn. State College Ext. Circ. 94. Profitable Potato Spraying.

vania results, which are comprehensive and based on the latest requirements, are not available at the present time.

Spray Rings and Cooperative Spraying. Some men have orchards, small fruit plots, or truck crops, which are too small to stand the overhead of a good power sprayer, yet really too large for hand outfits. How to provide these men with efficient equipment is often a big problem. The importance of high pressure, the application of plenty of spray material, and the use of the proper type of accessories is just as important for 1 acre or 5 acres of orchard as it is for much larger acreages, yet the limited output of these men makes the investment of money by each individual for a power outfit a questionable investment.

The solution of the problem has been found in Iowa and certain other places by forming spray rings for orchard spraying and a similar organization has been developed for the spraying of potatoes and other vegetable crops in Pennsylvania. A good machine is cooperatively owned by two, three, or four growers who use the outfit alternately throughout the season.

Where the group of owners is larger a university student or someone else qualified to operate the outfit is put in charge. This arrangement differs from custom spraying in that the owners control the outfit and the manner of applying the spray, while in custom spraying they must rely on the knowledge, efficiency, and honesty of the operator. Equipment and materials are purchased cooperatively and paid for on a share basis. Each acre of potatoes or fruit sprayed constitutes one share. A total cost for a season to a ring of this sort may be about \$1000 and from 60 to 100 acres have been sprayed by one outfit in this way, the acreage varying with the size of the individual fields and the distance between farms. By this means the work may be placed in competent hands, the best equipment is made available, and the applications may be made at the proper time without interfering with other important work, such as haying or harvesting.

Power outfits may be secured which are adapted to spraying both orchards and low-growing crops. To spray trees it is only necessary to remove the spray boom and attach a lead of hose and nozzles suited to orchard spraying. Such an outfit should have at least $3\frac{1}{2}$ horsepower and a capacity of 8 gallons per minute.

Is Hired Spraying Efficiently Done? Various sections of the country have a few growers who patronize men equipped to do

custom spraying. Those who do not have a sufficient acreage to justify the purchase of a power sprayer and wish to avoid the laborious work of operating a hand pump resort to the hired sprayer.

The observations of Messrs. Folger and Thomson¹ are most interesting and valuable on this point. "In considering custom spraying, two decided disadvantages weigh heavily against this practice. In the first place, the value of spraying and its relative cost may only be measured by its efficiency. No matter how cheap the cost, careless spraying is expensive. To be efficient, a spray must be applied at the critical period. If one has to wait for a custom sprayer, very often the value of the spraying is partly lost. The second reason is that while figuring only labor and material costs the hired sprayer may be cheaper, it is considerably less efficient. On 69 fruit farms studied in the Yakima Valley 39 growers owned their own sprayers and 30 hired their spraying done. In every instance the custom sprayer applied on the average of one-third less material to a tree. It is quite likely that in every instance this was false economy. The hired outfit will not perform the careful work which a grower himself will do."

Regional Problems in Spraying. Eastern growers have for the most part been successful in controlling codling moth by spraying and they sometimes wonder why this pest is such a serious problem for the western grower. Investigators at work for the U. S. Department of Agriculture who are in a position to make careful comparisons in pest control find that the arid climate in nearly all irrigated sections is favorable to the codling moth. Grand Junction, Colorado, and the Yakima Valley, Washington, are examples of sections where injury from codling moth is excessive, even though spraying is much more thoroughly and frequently done than in the East.

Likewise certain regions have much more difficulty in controlling San José scale. Many things enter in to affect the degree of control obtained, but perhaps the most important from the entomological standpoint are the length of season, which determines the number of generations of scale, and other favorable conditions of a seasonal nature.

Unsatisfactory control of San José scale has been reported

¹ Folger and Thomson, Commercial Apple Industry of North America, p. 233.

more often in the last two or three years than formerly. Dr. W. A. Ruth,¹ of the Department of Horticulture, University of Illinois, has made a survey among the orchardists of that state and concludes that the conditions necessary for success where the insect is most troublesome are:

1. "The diluted spray must contain 15 pounds of sulphur² in 50 gallons." 2. "The entire surface of the tree must be covered." 3. "The trees must be heavily covered. The experimental work does not indicate that lime sulphur of the strength recommended will control San José scale, if applied lightly, even if every part of the surface is covered."

The result of investigations conducted by the Oregon Experiment Station show that for trees between 11 and 17 years of age the amount of spray mixture required for the best results for dormant spraying is as follows:

Orchards: 11 years old.....	4.1	gallons
12 years old.....	4.5	gallons
13 years old.....	5.16	gallons
14 years old.....	7	gallons
15 years old.....	7.2	gallons
17 years old.....	8	gallons

At this rate trees 25 years old would require 13 or 14 gallons.

Investigations conducted by Dr. Ruth at Urbana indicate that even under favorable conditions for spray application these amounts are necessary to secure heavy and complete covering of the tree, yet the replies from growers indicate that the amount most frequently applied to 25-year-old trees is 5 gallons. It is probable, therefore, that lack of thoroughness in spray application, as evidenced by incomplete covering of the tree and an insufficient amount of spray material, is one of the most important causes in the failure to control scale.

Over a period of years apple blotch is, without doubt, the most serious disease affecting apples in the southern portion of the Middle West. Bitter rot is less troublesome and is usually controlled by the sprays applied for blotch. In the Ozarks, and more particularly in Virginia, probably the heaviest loss comes from bitter rot.

¹ Ruth, W. A., University of Illinois, Station Circular 252, An Explanation of Recent Failures in San José Scale Control.

² This amount of sulphur is equivalent to a 5° Baumé dilution.

Apple scab is the pest most feared in the northern coastal and lake regions of this country, including Michigan, New York, New England, and the fruit valleys of Oregon.

In New York certain localities suffer considerably from infestation of the apple red bug, and in New England the gipsy and brown-tailed moths have been a source of great trouble and expense to growers.

In the Watsonville district of California, growers must protect their apples from the inroads of the Tussock moth, leaf roller, and powdery mildew, and the two pests named last, together with apple blotch, bitter rot, scale, and excessive infestation of certain other pests, are not effectively controlled by dusting.

In commercial potato regions we find late blight a serious problem in Wisconsin, Michigan, New York, and New England. In other sections this disease is not considered serious enough to require special attention in the spray program. In certain regions leafhoppers are very difficult to control, while in others they are not yet prevalent. The potato bug is found nearly everywhere and engages the attention of the grower where profitable potato production is carried on.

Among the vegetable crops, regional variations are illustrated in the tomato when it is grown for canning purposes. In Maryland, Delaware, New Jersey, and Virginia it is apparently profitable to spray for the control of Septoria leaf spot, but in Indiana it does not pay to spray the tomato crop destined for the cannery.

In Georgia spraying watermelons to control anthracnose is profitable, for the disease is a limiting factor there, but in Indiana it rarely occurs, and spraying would therefore not be practical.

Selecting the Proper Spraying Outfit. This is often a difficult thing to do, especially for the man who is buying his first outfit. In an orchard, for instance, the demands made upon a sprayer will increase rapidly with each succeeding year. If the trees are young an outfit which is adequate for the first year or two after it is purchased may not later have sufficient capacity to cover all the trees within the narrow limits of time available for effective spraying. Selection which involves details of construction and quality of materials has been considered in the chapter on "Spray Machinery," and the fact has been stressed that as a usual thing buying a machine because it is cheap is poor economy. On the other hand, buying an outfit which has greater capacity than is

needed increases the investment cost and the amount of depreciation unnecessarily.

In orchard work a problem arises where a man buys a power outfit with a triplex pump, having a capacity of 8 to 10 gallons a minute, for a 40-acre orchard 2 years old. The amount of spray applied per tree for the first year or two will be about 1 to 2 quarts for each application and the total amount of time required in a season to apply these sprays will probably not exceed 4 to 6 days. It is quite possible for the first 3 or 4 years, at least, to get satisfactory results with a good barrel pump. A tank pump will postpone, until the 5th or 6th year the need for securing a high-priced power outfit.

Granting that the use of a hand outfit is more laborious and that the labor bill will be greater, it is nevertheless an interesting question which each grower must decide for himself, as to whether he shall buy one type of outfit or the other. He must consider the interest on the investment, the amount of depreciation, the type of labor available, and other factors which may apply particularly to his own conditions.

Comparative Cost of Spray Outfits. There is a wide range in prices for spray outfits depending upon their capacity. In this discussion we shall not consider anything smaller than a barrel pump and the table which is given below shows in a comparative way the cost of various types of outfits and the amount of depreciation each year. Prices for the various types will change from time to time, but the relations between them, which is the purpose of this discussion, will not be seriously affected.

The rate of depreciation on most farm machinery is 10 per cent each year, but the exacting requirements placed upon spray outfits make the average depreciation about double that amount. We can readily think of cases where the depreciation is less than the average, both on farm and spraying machinery, but this was due to unusually good care, and such a rate cannot, therefore, be applied generally.

Orchard Sprayers Compared with Solid-stream Sprayers for Shade-tree Work.—The foregoing discussion might lead the reader to think that the expense of equipment necessary for solid-stream spraying would make it desirable to substitute the cheaper orchard outfit, but the conditions under which this kind of work must be done are entirely different. It is quite possible that

orchard sprayers having a capacity of 12 gallons per minute and maintaining 300-pounds pressure, at the pump, could operate a solid-stream nozzle with a $\frac{3}{16}$ -inch jet opening, but this would limit the work to the spraying of comparatively small trees. Since the outfits used for most shade-tree work must be so adaptable as to spray trees of all sizes within its territory it is obvious that this requirement eliminates nearly all orchard sprayers now on the market. Furthermore, it is a question whether most orchard sprayers are built to withstand continuous pressures of 300 pounds, while this is a normal and minimum working pressure for the other outfits.

TABLE VII

SHOWING TYPE OF OUTFIT, ORIGINAL COST AND AMOUNT OF DEPRECIATION

Type of Outfit	Original Cost	Amount of Depreciation at 20 Per Cent per Year
Barrel pump.....	\$35.00	\$7.00
Tank pump.....	\$75.00 \$ 100.00	\$15.00-\$ 20.00
Traction sprayer.....	85.00- 140.00	17.00- 28.00
Small-power outfit.....	300.00- 400.00	60.00- 80.00
($1\frac{1}{2}$ to 3 horsepower)		
Power outfit of medium capacity...	400.00- 650.00	80.00- 130.00
(3 to 6 horsepower)		
Large orchard sprayer.....	750.00- 1000.00	150.00- 200.00
(8 to 15 horsepower)		
Shade-tree sprayer:		
Outfit delivering 12 gallons per minute.....	575.00	115.00
Outfit delivering 50 gallons per minute, 300-pounds pressure mounted on truck.....	2250.00	450.00
Power truck sprayer complete....	5550.00- 5950.00	1110.00- 1190.00

If figured for a single year only, the low first cost of the orchard sprayer may make the total expense less than that of the other outfit, but for two or more years the solid-stream method will be found to be cheaper.¹ If a shade-tree sprayer costing \$1500 completely equipped is taken for an example we find that "It is

¹ Worthley, L. H., U. S. Department of Agriculture Bul. 480, Solid Stream Spraying against the Gipsy Moth.

safe to figure depreciation at the rate of 20 per cent each year, although there are machines in the field at the present time that have been used 8 years and have only required an annual overhauling and the replacement of small worn parts. In 20 days' spraying one large machine should treat 10,000 shade trees. This would average only 3 cents for each tree in depreciation which is not prohibitive to any municipality. Taking everything into consideration, the entire cost of spraying shade trees with the solid stream does not exceed 12 cents per tree if the work is managed properly. The following figures are submitted to show how the cost per day is computed for 20 working days."

1 pair of horses and driver.....	\$ 6.00
3 men, 8 hours each.....	7.50
560 pounds of poison at 5 cents per pound.....	28.00
10 gallons of gasoline.....	1.80
1 gallon of oil.....	.30
Depreciation per day at 20 per cent per year.....	15.00
	\$58.60

"The average number of shade trees sprayed with each 400 gallons of poison is 35, and 14 tanks (5600 gallons) in 8 hours is a good average, totaling 490 street trees per day, making the average cost per tree about $11\frac{3}{4}$ cents. In treating shade trees, where any considerable amount of spraying is to be done, the use of small outfits and mist spraying is much more expensive than the solid-stream method. In an experiment conducted during the summer of 1916 the cost of treatment with a small hand outfit was more than twice the amount per tree that it was when the solid stream was used. While one can find considerable variation in the cost of applying the mist spray, either with gasoline or hand outfits, it is more than double the cost of solid-stream spraying; which in the long run of the season's work will equal two-thirds the initial cost of a high-grade solid-stream machine and equipment. By following the mist method for two seasons a high-grade outfit has practically been thrown away and with no asset to show for money expended."

Although these figures do not represent the latest prices on materials, equipment, and labor, yet the comparisons answer fully as well. It is quite evident, therefore, that the spraying of

shade trees is an entirely different problem from spraying the orchard or garden.

ASSEMBLING AND OPERATING SPRAY OUTFITS

Most power outfits are shipped, knocked down, and crated to secure the most favorable freight rates, but the work of assembling is not difficult. Some companies have adopted the commendable practice of furnishing printed and illustrated instruction books on setting up and operating their outfits. Instructions should be followed closely if the greatest success in running the outfit is desired.

After the machine is properly assembled, bolts, screws, and bearings will need watching for adjustment until the newness wears off. The tank should be soaked to take up possible leaks, preferably a number of hours before spraying begins. The suction lines may need testing for air-tightness and the motor and pump will require proper lubrication. Before starting the engine turn it over by hand to make sure that all pump cylinders are working freely.

The details of operation and repair of the power machines will differ somewhat with each make and with new models so this information should always be obtained from instruction books furnished by the manufacturer.

Care of Outfits During Spraying Season. Someone has said, "Give your power sprayer the same care and attention that you give your automobile, motor truck, or tractor and it will render at least an equal service." A sprayer is subject to hard usage and this must result in rapid depreciation and heavy repair bills if such machinery is not given good care. Spray-mixture deposits allowed to remain in the outfit may hasten this process even more than exposed farm machinery deteriorates from rusting.

Proper care of a spray outfit is not difficult nor does it require a great deal of time. All wearing parts of the outfit requiring grease or oil should be frequently and well supplied. To remove corrosive spray mixtures the procedure for all types of sprayers from the smallest hand outfits to the largest power equipment is to run fresh water through all the working parts of the pump on through the waterways and the hose to the nozzle. This should

be done at the end of each day's work as well as at the end of a period of spraying.

When the outfit is to be put away for a period of time it is a good plan to pump a little cylinder oil into the pump after it has been cleaned. All parts having threads should be loosened and the threads well oiled. The packing is also loosened for oiling and the valves lubricated to prevent sticking. All drain cocks should be opened or drain plugs removed to drain all parts of engine, pump and tank. Even a small amount of water freezing in the outfit will result in broken parts, and if not discovered until spraying season the delay may cause considerable annoyance and expense. To make sure that all water is evaporated or forced out of the equipment some men start the engine and allow it to run for just a short time. Care should be taken if this is done not to allow the engine to become overheated. The spark plugs may be removed and wrapped in oiled cloth to prevent rusting. Cylinder oil may then be poured into each cylinder and the engine turned over a few times so that the oil may be worked in around the piston rings. Cork stoppers should be placed in the spark-plug holes to prevent moisture from entering the cylinders.

If the tank is made of wood it should always contain some water during the summer months to prevent drying out. In recent years certain owners of large orchards have required their spraying crews to wipe off the pump, engine, and tank with waste or cotton cloth dipped in cylinder oil. This removes the corrosive spray material, the dust and extra grease which accumulates, and keeps the outfit not only clean, but looking like new. Ten or fifteen minutes' time spent each day in this way is a good investment of time and certain growers keeping twelve to fifteen power sprayers consider this practice just as essential as grooming their horses each day.

The Daily Output of a Power Sprayer. Many factors affect the amount of spray mixture delivered by an outfit in the course of a day. The exact amount of the output is not so important as whether the outfit is operating efficiently under a given set of conditions. That they vary widely may easily be seen in the following table. All outfits considered are equipped with standard 200-gallon tanks, but there is some variation in the horsepower of the engine, and the larger orchards use outfits equipped with engines developing at least 3 horsepower.

TABLE VIII

SHOWING THE NUMBER OF SPRAY MACHINES REQUIRED IN SIX ORCHARDS
OF VARYING SIZE

Grower No.	Acres of Orchard	Number of Spray Machines	Acres of Orchard Per Outfit
1	140	12	11 $\frac{2}{3}$
2	400	12	33 $\frac{1}{3}$
3	900	30	30
4	1400	16	87 $\frac{1}{2}$
5	1700	34	50
6	3000	40	75

A glance at the table will show that Grower No. 1 is not getting a proper return on his investment in power sprayers. Grower No. 4 gets such unusual efficiency from his machines that one who is acquainted with the usual output may well wonder whether the work is thoroughly done. One thing which contributes greatly to this result is the overhead water system with 17 filling stations. It cost \$10,000 to install, but the grower is well satisfied with the expenditure. Another thing which contributes to the efficiency of each machine is the number of days they are operated each year. Two years ago each machine on his place averaged 140 days of work during the year.

Grower No. 6 has orchards scattered in a number of different counties, and under the circumstances the output of each machine is remarkably good. His machines deliver on the average 7 gallons of spray mixture per minute, and he expects each machine to put out ten tanks in a 10-hour day. This amount is above the average, but eight tanks ought not to be an impossible accomplishment. When the average is only six tanks per day the overhead gets heavy, and the manager should consider carefully whether he is getting all that he may expect from machine and crew under his conditions.

Another means of increasing crew efficiency is to have the man spraying from the tower do the driving. The conditions are unusual where a man is necessary who only drives.

Certain owners who must have many machines to do their work adopt the practice of numbering each one and preparing a

daily report sheet for each crew to turn in at night. By this means the owner knows the number of hours the outfit works each day, the number of tanks of spray mixture applied, whether the machine has been idle or not, and other information of similar value.

VALUE OF A SPRAY RECORD

There was a time when a planting plan of a commercial orchard drawn to scale and prepared in blue-print form was considered by fruit growers to be unnecessary work, but to-day a good many growers have a record of some sort which they have prepared as various blocks of trees have been planted.

At the present time very few growers keep a complete spray record, but it seems that the advantages are even greater for this phase of orchard management than for a planting plan.

In a large commercial orchard a manager cannot follow the work of several spraying crews in detail. It is not desirable to trust too much to the memory of the crews nor even to the manager. Stormy weather, a breakdown of the spray outfit, sickness of the foreman, or a necessary rearrangement of working crews at various times may result in neglect to spray certain trees or portions of an orchard, or may at least contribute to lack of thoroughness in the work. In such cases a definite daily record written up each night will enable the manager to keep the work going smoothly and efficiently. When continuous stormy weather makes it impossible to complete any one spray application in a portion of the orchard the harvest may show a distinctly noticeable amount of scale, scab, or blotch from that portion. The manager may recall having omitted one spray, but does not remember just how many trees were involved, and may have forgotten other information which a written record will supply. With this record before him his attack on these pests the following year may be definite as well as vigorous.

The manager with several spraying crews is somewhat at the mercy of the men in charge, and they in turn are no more efficient than the system they employ in performing their work. It generally follows that the managers who have a good working system in fruit production for themselves and for their men are most thorough in all phases of the work and are most successful financially.

In a region where codling moth is particularly difficult to control because it continues to appear until late summer and where apple blotch also exacts a heavy toll from the marketable fruit some growers have systematized their spraying to such a degree that they are able to grow a crop with a very high percentage of perfect fruit. Such men are finding a written spray record of some sort of great value in maintaining a fancy grade of fruit.

Any grower who is interested in working out a spray record may develop one suited to his own conditions by enlarging upon the planting plan of his orchard. Such a plan may be as simple or as elaborate as the individual may choose to make it.

A spray record which will give complete and accurate information to the orchard owner is well illustrated in the form of record prepared by the Simpson Orchard Company of Vincennes, Indiana. This company endeavors to grow fruit of fancy grade on a fairly extensive scale, 200 acres of land being devoted to apples and 60 to peaches. Their long experience enables them to appreciate the value of thorough spraying and of accurate knowledge of spray operations. As a result they have evolved the accompanying spray record.

Mr. R. A. Simpson is general manager of the field work having field foremen under him to carry out the details. At the end of each day the field foremen fill out the spray record for that day. When the spraying has been completed on all blocks, which usually requires six working days, the complete record is turned into the office. Three copies are taken. One is retained by the foremen, one is for the general manager, and the third is filed as a permanent record in the office. Mr. Simpson's explanation of this record sheet shows how useful it may be made.

Near the top of the left-hand margin of this sheet a space is left to indicate whether the spray is dormant or first, second, third, fourth, fifth, or sixth summer spray. Notes may be made under stage of development to indicate whether petals are all off or whether the apples are the size of marbles, quail eggs, etc.

Since the spray mixtures applied may change in kind or amount of ingredients, depending on weather, variety of fruit, and other things, it is important to know the exact formula used for each spray. Bordeaux mixture of standard 4-6-50 strength or mixtures as weak as 2-4-50 may be used with arsenate of lead added. With other sprays lime sulphur of 1° Baumé strength may

be substituted for the Bordeaux. In other instances in the late summer spray Mr. Simpson uses only arsenate of lead and milk of lime for certain varieties of apples not subject to the severe late summer diseases of his section. The record may here become unusually valuable, because it offers a memorandum for all these various spray practices.

Where the word "lead" appears on the sheet with a blank space in front of it, it was intended that the form and brand of lead used should be noted.

Under the heading "insects" should be noted the insects just appearing, as, for instance, codling moth or cankerworm. When these insects have more than one brood the particular brood just appearing should be noted. A disease record covering important points may be kept in a similar manner. The direction of the wind is important in relation to a day's operations as it will determine the direction which the spray outfit will take through the orchard. But comment on the wind may also include a record of exceptionally windy days or days when the wind is very cold.

The temperature for the day should be noted, but the main purpose of this item is to record the extremes of temperature, such as abnormal warmth or frosty and freezing temperatures. Over a period of years this record may be of considerable value in determining the time when danger from frost or freezing is over for that locality.

Under remarks, mention may be made that Bordeaux mixture was applied, for instance, on Duchess and Northwestern Greening, lead and lime on Grimes, and lime sulphur on the rest of the orchard.

Following down the left-hand margin of the record sheet the reader will find certain symbols repeated under each day of the week. The key for these symbols will be found near the right-hand upper margin of the record. Time is thus saved for the foreman in recording the kind of weather by making it possible for him to check the symbols which properly describe the weather. If it is clear in the morning and rainy in the afternoon this may be indicated by checking the two symbols representing such weather.

The direction of the wind, especially when it is strong, is very important in relation to spraying. Mr. Simpson believes that it is impossible to do an absolutely thorough job of spraying under his

conditions by going over the trees once. He wants to know definitely the direction of the wind at the time of all spray applications, so he makes a record concerning the wind the first time through the orchard and plans to complete the application of that spray when the direction of the wind has changed so that he may most effectively cover the tree. His men are instructed to cover as nearly two-thirds of the tree as possible the first time, and when these trees are sprayed from a different direction their main purpose is to cover a similar area of each tree from the opposite side. Only with this amount of overlapping does he feel sure of thorough work. Readers who feel that this amount of care is not necessary should remember that in the latitude of Vincennes the winters are mild and San José scale exceedingly troublesome. Also that apple blotch in the late summer requires very thorough spraying if it is to be controlled.

The date on the record blank should include the beginning of any one spray and the date when the spraying of the entire orchard has been completed, so that if six sprays are applied during one season, six record sheets in the files will give all the necessary information for that year. This form can also be used for other purposes. For instance, if certain trees are infested with San José scale or with diseases these facts can be added to it. The blocks receiving different kinds of fertilizer or plats receiving cultivation or sod mulch treatment might be indicated. The location of ponds, tile, and tile openings can also be indicated. The plan not only shows the variety of each tree, but the dots represent the fillers which are to be removed when necessary, while the circles show the permanent trees. The date when each block was planted is printed on it and the back of the record sheet may be used for any additional notes that might be of value to the owner.

CHAPTER VIII

PRACTICAL HINTS ON RUNNING A GAS ENGINE¹

NEEDLESS WASTE OF LABOR

THE gas engine, a great labor saver on thousands of farms on which stationary engines, tractors, motor trucks, automobiles, or power sprayers are operated efficiently, is also at times the cause of a great waste of labor. Often large crews hired to help with thrashing, hay-baling, cutting ensilage, etc., draw full wages for hours spent in idleness, owing to inefficient handling of the engine. A man frequently will spend much more time and energy in starting a gas engine to pump water for stock, run a milking machine, or to start a sprayer engine than would be required to do the work by hand. The time lost throughout the country in this manner, enormous in the aggregate, is, to a great extent, preventable.

It is not desired to convey the impression that gas engines usually give trouble, or are difficult to operate, for this is by no means the case. Delays from engine trouble are usually due to the operator's ignorance of some of the details essential to proficient operation. The purpose of this bulletin is to assist in conserving farm labor by offering some practical help to persons whose duty is to operate gas engines. It is not intended as a course of instruction for those totally unfamiliar with the principles of gas-engine operation. The aim is merely to call attention to some of the more common causes of trouble with gas engines, suggest a method of locating quickly the seat of trouble when an engine fails to run as it should, and offer a sort of reminder in the form of a condensed trouble chart, which, it is believed, will frequently be of assistance even to the more experienced engine operator. The suggestions and information are general, no attempt having been made to make them directly applicable to each of the many types of engines.

¹ Adapted from U. S. D. A. Farmers' Bul. 1013, by A. P. Yerkes.

USE ALL INFORMATION FURNISHED BY MANUFACTURERS

All catalogues and directions furnished by the manufacturer should be studied carefully. If none are received with the engine, a request for them should be sent promptly to the manufacturer. It is to be regretted that a few manufacturers are rather lax in the matter of furnishing such material, although it is obviously to their interest to make use of this comparatively inexpensive method of assisting the purchaser to obtain satisfactory service from the engine.

ANY INSTRUCTION BOOK FURNISHED BY THE MANUFACTURER SHOULD BE KEPT IN A SAFE PLACE, BUT CONVENIENT FOR REFERENCE.

It is safe to assume that the man who made the engine knows something about its operation and can give some information of value to the purchaser. In altogether too many cases the instruction book and other literature intended to be of assistance to the user of the outfit are either thrown away or ignored completely, and not infrequently a man is sent from the factory, or a local expert is hired, to make simple adjustments concerning which full instructions are given in literature furnished by the manufacturer but which had never been read by the owner.

LUBRICATION

A large percentage of repair expenses is due to insufficient or improper lubrication. In far too many cases owners of gas engines use grades of oil entirely unsuited to their engines, notwithstanding the fact that in each case the manufacturer has furnished a long list of various brands and grades of oil which have been tested and found suitable to the engine in question and which can be obtained practically anywhere in the country.

Another common error is to use too little oil. It is poor economy to try to save on oil. On the other hand, an excess of oil in the cylinder, while better than too little, will cause carbon deposits, followed by loss of power, over-heating, and preignition. Heavy, bluish smoke from the exhaust indicates that the cylinder

is getting too much oil, but it is usually advisable to furnish enough to give at least a slight trace of bluish smoke.

If the cylinder is oiled from the crankcase by the splash system, the lubricant being used over and over again, the oil should be examined frequently, and as soon as it becomes badly discolored or very thin it should be drained out and new oil substituted. Many manufacturers furnish directions as to how this should be done. Filling the crankcase with kerosene after draining out old oil, and then running the engine a few minutes without load, in order to remove dirt and carbon from bearings and other parts, is frequently recommended. This is good practice where the crankcase can be drained completely, but on many engines there are pockets which cannot be fully drained, and the kerosene remaining in these pockets will thin the new oil. Under such circumstances the rinsing is of doubtful value. After such rinsing is done, the engine should not be run at full speed or under load until the new oil has had ample time to reach all bearings. The dirty oil drained off may be filtered and used for oiling other farm machines, but it should not be used again in the cylinder. If the oil in the crankcase quickly becomes thin it is evident that some of the fuel is getting past the piston rings. This seriously affects the lubricating quality of the oil. It should, of course, be replaced with fresh oil, and steps taken to improve the carburetion so as to form a fuel mixture which will burn more completely.

KEEP ALL NUTS TIGHT

It requires but a minute or two to go over an engine and see that all screws and nuts are tight, at the same time wiping off any oil and dirt which have collected. This should be done at least once every day the engine is used. Such practice will go far toward preventing many operating troubles, since all gas engines vibrate to some extent and this vibration tends to loosen bolts, nuts, and other parts. This is always a potential source of breakdowns, if not of serious accidents. Furthermore, loosening of parts often results in a loss of power.

EVERYONE WHO OPERATES A GAS ENGINE OF ANY KIND SHOULD LEARN FIRST TO STOP AND REASON AS TO THE PROBABLE CAUSE OF ANY TROUBLE WHICH DEVELOPS.

In most cases where an engine stops, loses power, or indulges in some other irregularity, some indication of the cause will be apparent to anyone familiar with the outfit if he studies the problem intelligently. Such study will enable one to avoid needless tinkering with parts that are working properly. Even should the cause of trouble not be apparent after a little reasoning no attempt should be made to locate it by a general change of adjustments or tinkering done in a haphazard way, as this method will very frequently add to the trouble.

A DEFINITE SYSTEM SHOULD ALWAYS BE FOLLOWED

Not only will this go far toward insuring success in locating the trouble, but it will, in nearly every case, save time, for unless the trouble is a very unusual one it will be located in one going over. Practically all experienced operators, in hunting for the source of trouble with gas engines, follow, whether consciously or not, a more or less uniform system of tests. Just what order these tests should take will depend upon the particular make and type of engine; the tests which can be made most quickly and easily should, of course, be made first. From the points mentioned in the following pages it is believed that any operator who does not already employ such a system can readily devise one which will be best suited to his particular engine.

STARTING TROUBLES

Always bear in mind that for a gas engine to run it is necessary to have a compressed mixture of vaporized fuel (generally gasoline or kerosene) and air in proper proportions, which is exploded by a hot spark while the mixture is under compression. The spark should occur slightly before full compression, except in starting, when it should occur just after full compression has been passed.

When an engine refuses to start, the trouble will, with a very few exceptions, be due to some interruption of the supply of the

proper mixture of gas and air, or to a failure of the electrical system which furnishes the spark to fire the compressed mixture. It seldom happens that both systems are at fault at the same time, so the first thing to do is to find out whether one of these systems has ceased to work properly.

The ignition system, on the whole, is more often the cause of trouble than is the fuel system, and it is usually advisable to test this first unless, on account of the construction of the particular engine in question, it is easier to make tests for troubles with the mixture supply.

TESTING THE IGNITION SYSTEM

With all engines using spark plugs it is comparatively easy to ascertain whether the ignition system is working properly. Simply remove a plug and ascertain that the porcelain or other insulating material on the inside of the plug is not coated with carbon and that the points are properly spaced. One thirty-second of an inch is about the right space for most systems where a dry battery is used. This is about equal to the thickness of a worn dime. A wider gap will often make starting difficult, especially when the spark is rather weak or where a high-tension magneto is used. In the latter case the best results will often be obtained when the gap is not more than $\frac{1}{40}$ or even $\frac{1}{50}$ of an inch. Then reattach the wire and lay the plug so that the metal base touches the engine casting, while the end of the wire and the metal tip of the plug are at least half an inch from any metal part connected with the engine and in such a position that the points are visible while cranking the engine. Then turn the engine over a few times (at least as many times as there are cylinders) and note whether a spark jumps across the space between the points. It is not sufficient, however, merely to ascertain if there is a spark—it must be hot enough to fire the compressed charge in the cylinder. It is, of course, difficult to tell by merely looking at it whether the spark is hot enough or not, but if it is a heavy blue, or a bluish white, or a “fat” yellow one looking like a small flame, it is probably all right. If very thin and greenish, or showing red, the chances are it is too weak to fire the charge. One may familiarize himself with the aspect of a good spark as follows:

While the motor is in satisfactory running condition loosen

the nut on the top of one plug while the engine is stopped so it will be easy to remove the wire from the plug after the engine is started. Then start the engine and, by taking hold of the wire where it is covered with insulation, move the end of the wire very slowly away from the center of the plug and watch the spark jump, closely observing its color and thickness.

It is also well to note the distance the spark will jump, yet not advisable to force it to jump too great a gap, nor should the end of the wire be allowed to rest in a position where the spark cannot jump to the plug or the engine while the engine is running, as this tends to break down the insulation of the coil. In the case of high-tension magnetos there is no danger in this respect as they are fitted with a safety spark gap which the spark will jump, if for any reason the circuit is broken elsewhere.

Knowledge of just how much of a spark one should obtain with each kind of ignition system is frequently of great value in locating trouble, and everyone who operates a gas engine should make the above-described tests while the engine is in good order. If one is not sufficiently familiar with the looks of a good spark to tell by mere observation whether it is hot enough, a rough test may be made as follows: place a thin piece of dry cardboard, such as an ordinary visiting card, or three or four thicknesses of dry newspaper, between the points of the plug while it is lying on the engine in the position first mentioned, then crank the engine. A good spark will jump through these, leaving a tiny hole. A spark which will not do this is too weak to jump the spark gap in the cylinder under compression.

If the engine is equipped with a make-and-break ignition system, in which an igniter block is used instead of a spark plug, it can be ascertained easily whether the entire system, with the exception of the igniter block, is in good shape by disconnecting the wire from the igniter block and snapping it across the corner of the engine casting or the end of the other wire leading from the coil. But even though this gives a good spark it does not necessarily mean that the spark is given in the cylinder when the engine is turned over. It may be that the points of the electrodes inside the cylinder do not touch each other when they should or are not making a good contact because carbon, oil, dirt, etc., have accumulated between these points. Therefore, if a good spark occurs when the wire is snapped across part of the engine,

crank the engine until the movable electrode is released and allowed to fly back.

If one is not sure just when the points of the electrode should be touching, the engine may be cranked very slowly for two full revolutions while the end of the wire is repeatedly snapped across its connection on the electrode. If no spark can be obtained at any position of the electrode, it is evident that contact is not being made by the points inside the cylinder (this is in case the other wire is grounded directly to the engine). Sometimes the other wire is fastened to a piece of metal insulated from the engine, but which touches part of the engine for an instant when the spark should occur in the cylinder. In this case if a spark can be obtained by bringing the ends of the two wires into contact it should be determined whether the insulated piece is making contact with the engine properly.

If no spark is obtained at the plug or igniter block when tested as directed it will, of course, be necessary to look over the electrical system in order to ascertain what is wrong. The electrical systems of various engines differ considerably and no definite instruction can be given for different makes, but some general points will be mentioned. First of all see that the switch is in starting position. Much time has been lost in thousands of cases by trying to start the engine with the switch off. When the engine is one with which the operator is familiar he will, of course, know the proper position of the switch for starting. In all cases where a battery of dry cells is used, the switch should be closed. Some engines, however, are started with a spark from a magneto, for which the switch is in starting position when open.

Next look over all wire connections to see that they are tight and clean. If the engine starts on a battery of dry cells see that all connections between the cells are tight and that no short circuits are caused by the metallic portions of the cells touching each other, or by metal connection with the engine, or by tools lying on the cells, etc. The small knurled nuts on dry cells frequently loosen from vibration and thus interrupt the whole ignition system.

It is a good thing to keep an ammeter handy for use in testing the strength of the cells of a battery. In testing with an ammeter it is best to discard all cells that do not test over 12 amperes. A new cell should test between 20 and 30 amperes. If no ammeter

is available a crude test can be made by striking the end of the wire connected to a cell at one end against the first connection on the cell at the other end.

DO NOT KEEP THE WIRE IN CONTACT WITH THE CELL FOR MORE
THAN AN INSTANT

Doing so will weaken the battery, but by snapping it quickly across the edge of the knurled nut a few times and noting the sparks, one can ascertain whether the battery is producing a good current. By making this test a few times with a battery which is in working condition one can easily learn about how much of a spark should be expected. The sparks in this case will not be so intense as those produced at the spark plug by the coil, but when the wire is snapped across the milled side of the nut on the dry cell there should be a sputtering succession of tiny sparks.

Another crude test by which one can soon learn to tell whether a dry cell is in good working condition is to touch at the same time with the tongue both the carbon and zinc connections on the cell. By making a few experiments with dry cells of various strengths one soon is able to tell whether the cell is generating sufficient current for ignition purposes. There is absolutely no danger and no discomfort. There will merely be a slight tingling sensation and a sort of acid taste which will vary according to the strength of the cell.

If the ignition system is one which utilizes the current from a magneto, and no spark can be obtained at the plug, though the wiring seems in good shape, the trouble may possibly be in the magneto. Present-day magnetos, however, are very reliable and not likely to give much trouble in this respect. In most cases where there is good evidence that the magneto is at fault it should be taken to an expert for repairs. An inexperienced person should never attempt to take a magneto apart; this is a job for an expert, or at least a good mechanic who is equipped with detailed instructions for undertaking the work. There are only a few things which may be done safely by an inexperienced person to remedy a defective magneto, and these may be done without taking it apart.

Sometimes too much oil will cause trouble by accumulating on the contact points in the breaker box. It is usually easy to

examine these points and see if they have oil in them, are rough or pitted, or not opening properly. If oily, rinse with a little gasoline and wipe dry. If rough or pitted, the points should be smoothed with a file made especially for this purpose. If such a file is not available a small knife blade may be used to remove the tiny tips of metal which have formed on the points and to round off the burred corners. It pays, however, to keep a suitable file on hand for this work, for pitted points are not uncommon, and unless properly smoothed up are liable to get into bad shape again very quickly. A guage is generally furnished by magneto manufacturers to determine the proper distance between the points in the open position. The means of adjusting this distance vary with different makes of magneto, but are usually apparent upon examination. The points should separate about $\frac{1}{50}$ of an inch. An ordinary pin is about $\frac{1}{32}$ of an inch in diameter and a fairly close estimate may be made using this fact as a criterion, if no guage is available.

There is one other thing which the inexperienced operator may do to the magneto, and that is to see that the commutator brush, which may be made of wire gauze or carbon, is clean. Sometimes dirt or oil will collect on this brush and interfere with the electric current. The location of this brush varies on different makes of magnetos, but it is always located where it can be removed and cleaned easily.

Aside from these two things, however, the ordinary operator should not tamper with the magneto. There are few other things which may go wrong with it. These can be remedied only by an expert with special tools, etc., and it is extremely easy to do it harm. Simply removing the magnets without placing "keepers" on them (iron or steel bars to connect the poles) will materially weaken them, yet this is something the inexperienced person frequently does.

It is important that a waterproof cover be provided for the magneto, especially in the case of engines used out of doors, such as gas tractors, in order to protect the magneto from moisture and dust as either of these is likely to cause trouble sooner or later.

During the past few years many stationary gas engines have been equipped with low-tension oscillating magnetos. Some of these are mounted directly on the igniter block, and it is easy

to test the spark by removing the block and tripping the oscillator with the means provided. In other cases it is necessary to remove the end of the wire attached to the igniter block and wipe it across a metal part of the engine, at the same time tripping the oscillator. It is necessary that the end of the wire leave the metal almost instantly after the oscillator is tripped, otherwise the spark will not occur. A little practice will make this test comparatively easy.

TESTING THE FUEL SYSTEM

When an examination has shown that a good spark is being obtained at the right time, the next step is to see whether the engine is receiving the proper mixture of fuel and air. Many carburetors are made so that it is easy to remove the cover and see whether there is gasoline in the bowl, and where this is possible it is the easiest way to determine whether the fuel supply is all right up to that point. Other types of carburetor have tight covers, but are equipped with small petcocks, by opening which one can determine whether a supply of fuel is available.

If there is no fuel in the carburetor, either the tank is empty or there is some obstruction in the pipe line between the tank and the carburetor.

To see that the carburetor contains a liquid which looks like gasoline, however, is not enough, as water and gasoline look very much alike, and it is not at all uncommon for water to be present in the gasoline system. Neither does this water always enter the system when it is being filled, as is generally supposed. It is often the result of condensation of moisture on the sides of the gasoline tank, which runs down and settles at the lowest points in the system. This may be in the bottom of the carburetor, in the supply pipe, or in the strainer or settling chamber. Where strainers or settling chambers are provided, these should be drained and cleaned frequently, especially in cold weather, when any water present may cause considerable trouble by freezing.

A petcock on the carburetor is a good means for removing any water which may have settled at the bottom of the bowl of the carburetor, and which when present will cause difficulty in starting. When making a test in this way it is usually advisable to allow enough gasoline to run through to make sure that the carburetor has a full supply, as sometimes a partial stoppage of

the pipe will allow a small amount of gasoline to get by into the carburetor, but not enough to allow the engine to start easily. Allowing a half cupful of fuel to run through it eliminates this possibility. It is easy to ascertain whether water is present in the carburetor by catching in a glass bottle or tumbler the liquid which runs through when the petcock is open. Any water present will settle at the bottom of the glass and a thin line will be visible between the water and the gasoline.

It is not enough merely to have fuel in the carburetor; it must be mixed with the proper amount of air as it is drawn into the combustion chamber. It sometimes happens that the needle valve is closed or stopped with dirt, and that while there is fuel in the carburetor none can get into the combustion chamber. If the engine has a petcock leading into the combustion chamber, by opening this and cranking the engine a few times one can tell by smelling the escaping air whether gasoline is entering the chamber. The same result can be obtained by smelling the exhaust when the engine is turned over, or by removing a spark plug, closing the hole during the suction stroke and opening it during the compression strike.

By alternately opening and closing the needle valve, first being careful to note the original position so that it will be possible to readjust it if necessary, it is easy to see whether a different mixture will make the engine start. Or, when there is doubt whether enough fuel is entering the cylinder, a small quantity of gasoline (about a teaspoonful) may be poured into the combustion chamber through the priming cock or spark-plug hole and allowed to stand for a minute or two to vaporize and mix with the air before cranking the engine. If then one or two explosions occur, and no more, it is an indication that only the priming has burned, and that fuel is not being furnished in sufficient quantity through the carburetor.

It sometimes happens that too rich a mixture of fuel and air enters the combustion chamber, which is practically as bad as no fuel at all, as the rich mixture cannot be exploded by the spark. This does not often happen with a cold engine and with the grades of fuel now on the market, but it is not at all uncommon with a warm engine. There are several ways of overcoming this difficulty. Closing the needle valve and cranking the engine a few times will remove the rich mixture quickly and replace it with

practically pure air. Removing a spark plug or opening a pet-cock leading into the combustion chamber and then cranking the engine slowly a few times may answer the purpose, although as long as the needle valve is open some fuel will continue to be drawn into the cylinders.

TESTING THE COMPRESSION

It seldom happens that the compression of an engine suddenly becomes so poor through ordinary wear as to make it impossible to start with the methods commonly used. An open valve, however, will bring about this result. Anyone who has ever started a gasoline engine when it was in good working order should be able to tell at once whether the compression is entirely gone as soon as he undertakes to crank the engine. When compression suddenly fails it is probable that the cause is one of those shown in the trouble chart on pages 332-334, and the remedy is usually obvious when once the cause is located. The hiss made by the escaping air during the compression stroke is often enough to indicate the place where it is escaping.

STARTING IN COLD WEATHER

It is important that engine operators familiarize themselves with the bad effects produced on gas engines by cold weather and with the easiest way of overcoming them, for with such knowledge it is comparatively easy to start a gas engine in the severest weather.

The cold affects starting in three ways: (1) it makes it harder to crank the engine, because the oil congeals on the bearings and around the piston and valves, (2) where a dry battery is used it weakens the spark, (3) it causes gasoline to vaporize very slowly or not at all, therefore makes it difficult to obtain a mixture of gasoline vapor and air which can be ignited by the spark.

The congealing of the oil is not usually a very serious difficulty, although it may necessitate a great deal more effort in cranking the engine. A little gasoline or kerosene on all bearings which can be reached will help, and a liberal priming of gasoline in the cylinder will tend to thin the oil around the piston as well as aid in obtaining a good mixture, as noted below.

DO NOT USE KEROSENE IN THE CYLINDER TO MAKE THE ENGINE CRANK EASIER

It will interfere with the forming of a combustible mixture. Also where gasoline or kerosene has been used on bearings to make cranking easier, the engine should not be put under a load until the bearings have had time to get well lubricated again with good oil.

The effect of cold on the ignition system will be noticeable only where dry cells are used, with the exception that where the engine is equipped with a timer which is oiled, the congealing of the oil may interfere with the contact of the timer, in which case a little kerosene or gasoline may be necessary to thin the oil. When dry cells are cold they become less active, and at extremely low temperature they will cease giving a current. Therefore a dry battery should be kept in a warm place during the winter when not in use, so as to be active when needed. If this has not been done it should be set in a warm place for several minutes before attempting to start the motor in cold weather. Never warm a battery by applying intense heat directly to the cells, but allow them to warm slowly. While in operation they will generate sufficient heat to keep them active. With cells which have been sealed in paraffin or other wax, care should be exercised not to expose them to a temperature high enough to melt the wax.

The most serious effect of cold weather on gas engines operation is attributable to the fact that cold retards the vaporizing of the fuel. Gasoline as a liquid will not burn; it must first be turned into a vapor and this vapor mixed with a certain amount of air. A thin spray of gasoline in warm air will quickly turn to a vapor and mix with the surrounding air, but at low temperatures a considerable part of such a spray will remain a liquid, hence will not make an explosive mixture. The remedy is obvious. A greater quantity of gasoline must be furnished so as to give off more vapor in order to make a mixture rich enough to be combustible, or the air must be heated so the gasoline will vaporize more readily, or a combination of these expedients must be tried.

If the weather is only moderately cold, it is usually sufficient to prime the engine in some way, that is, inject a small quantity of gasoline (about a spoonful) into the cylinder, ordinarily either through a petcock or priming plug, in order that more fuel may

be present, hence, more vapor. Whenever an engine is primed a short time should be allowed for the fuel to vaporize and mix with the air before attempting to crank the engine. If this is not done the vapor will pass out a little at a time through the exhaust valve as the engine is cranked, and the priming will not serve its purpose.

In very cold weather, however, priming with ordinary commercial gasoline will sometimes be insufficient, and heat must be applied by some means in order to produce vaporization of the fuel, unless a more volatile fuel is used for priming. A very satisfactory way to apply heat is to put some hot water into the cooling system, thus warming the cylinders and assisting in vaporizing the gasoline that is drawn in with the charge or injected as priming. In this case, also, the engine should be allowed to stand a few minutes to permit the gasoline to vaporize. It is not necessary that the entire cooling system be filled with hot water; if enough is used to heat the cylinders so the engine will start, cold water may then be added until the radiator is full. This method, of course, will be practicable only with small or medium-sized engines; with some of the larger sizes of tractors the amount of hot water usually available will have little effect used in this way.

If only a little hot water is available it may be more effective if poured slowly over the intake manifold, and the carburetor as well, if the carburetor is covered so no water can enter it. A very effective way of heating the intake manifold is to wrap a cloth around it and pour the hot water over the cloth, or dip the cloth in hot water and then wrap it around the manifold.

If the manifold can be heated it will warm the air that touches it as it enters the engine; this warm air will cause the gasoline spray which it carries to vaporize. As a greater proportion of the air passing through a small pipe comes in contact with the walls of the pipe than in the case of a large one, this method works best with engines having a comparatively small manifold. When depending upon heat from the manifold to warm the air the engine should be cranked fairly rapidly, so as not to allow the warmed mixture to remain long in contact with the cold walls of the combustion chamber and so cause the vapor to condense into liquid again.

There are frequently occasions when an engine must be started in cold weather under conditions where hot water cannot

be obtained, and in such cases some other means of applying heat must be used. Some people make use of a blow torch to apply the heat to the intake manifold, or, by removing a spark plug or igniter block, heat the combustion chamber itself.

The use of an open flame around a gas engine at ordinary temperatures is not to be recommended, on account of the possibility of fire. It always introduces an element of danger.

One of the most effective methods of starting a cold engine, and one absolutely safe, is to remove the spark plug (or igniter block) and heat it in a fire or in the flame of a blowtorch, prime the engine, and then quickly replace the spark plug. The charge is almost sure to ignite. A drop or two of gasoline put on the inside of the plug just before replacing it insures the presence of vaporized fuel near the spark when the engine is cranked.

Where for any reason it is impracticable or inadvisable to apply heat in any of the ways indicated it may be possible to heat a piece of metal pipe the size of the air intake of the carburetor, then place this so all the air entering the carburetor must pass through it. This is nearly as effective as a heated manifold. Such a pipe may be made red-hot if desired.

Another means of starting engines in cold weather, which is practiced to a considerable extent, is to provide some very volatile fuel with which to prime it, ether or "high-test" gasoline being perhaps most commonly used. As these will vaporize at lower temperatures than ordinary commercial gasoline they make it easier to obtain a combustible mixture. In using ether, care should be exercised not to use too much, as dangerous pressures may be created because of the rapidity with which it burns. In many cases it is used mixed with about equal parts of gasoline. There is no danger in the use of the high-test gasoline. It is not quite so effective as ether, because it is less volatile, but it is being used with entire satisfaction by a great many engine owners.

IMPORTANCE OF THOROUGH KNOWLEDGE OF GAS ENGINE .

Because of the economic value of the gas engine for many kinds of farm work, and the fact that this machine seems destined to be used more and more for such purposes, it is highly desirable that at least one person on every farm where a gas engine is employed should understand fully the principles of its operation.

The importance of this point cannot be over-emphasized. Excellent opportunities are offered to enable anyone to obtain an education of this kind. The various state colleges usually have short courses in gas-engine operation. These are conducted by thoroughly competent men, experienced in teaching, and usually with first-class facilities and equipment for this work. These courses are already popular, but it is believed that if their value was more fully appreciated by farmers the attendance would be very much greater. Numerous private schools also specialize in this line.

For those persons who cannot avail themselves of these opportunities there are excellent books on the subject, and various publications with a large farm circulation carry "home courses" designed to reach these very people. A course of instruction under a capable instructor, with working models, is much to be preferred, of course, but if it is impossible to take such a course, it is highly advisable to spend a little spare time in studying the subject from books.

TROUBLE CHART

There are nearly always several different things which might produce any one of the various troubles common in gas-engine operation, and, as already pointed out, unless the operator takes time to reason the matter out, he is very apt to jump to a conclusion which is quite likely to be a wrong one. The exact cause of a trouble will frequently not be apparent at once even to the most experienced operator, and the use of the accompanying chart showing the possible causes of the various irregularities will often save considerable time by acting as a reminder of such causes. With these in mind, a little reasoning, and perhaps a few tests, nearly always enable one to reach the correct conclusion.

TROUBLE CHART FOR GASOLINE ENGINES

Loss of Power

Ignition: Spark occurring too late; spark weak because of partial short circuit or battery becoming exhausted; dirty spark plugs; poor connections; dirty timer; poor or broken wiring in case of magneto; breaker points worn, oily, or out of adjustment; commutator brush dirty or oily.

Fuel: Mixture too lean or too rich; supply pipe partly clogged; inlet valve not opening sufficiently due to wear; water in gasoline; leaks around intake manifold.

Motor: Overheating in cylinder or bearings; gummy, inferior, or insufficient oil; exhaust pipe partially clogged; governor out of adjustment; lack of compression which may be due to worn, stuck, or broken piston rings; scored cylinder walls; leaks through and around head joints; valves sticking, worn, pitted, or not seating properly because of dirt; in cold weather engine and cooling water too cold.

Misfiring

Ignition: Weak batteries; poor connections; dirty timer; vibrator points pitted or dirty; dirty or cracked plugs; points of plug not properly spaced; make and break points not touching properly.

Fuel: Mixture too lean or too rich: gasoline passage partly clogged; water in gasoline.

Motor: Lack of compression; valves sticky or not working properly.

Pounding

Ignition: Spark too early.

Motor: Red-hot carbon deposit in cylinder; loose bearings; tight piston, due to lack of oil or lack of cooling water; hot bearings; loose flywheel; very loose piston (piston slap).

Backfiring

Ignition: Spark too late. (If motor backfires and stops, spark may be too far advanced); short circuit on primary wire; wires to wrong plugs.

Fuel: Weak mixture; occasionally too rich mixture.

Motor: Leaky or stuck intake valve; red-hot carbon deposits; leaky manifold or carburetor gasket.

*Explosion in Exhaust Pipe*¹

Ignition: Irregular ignition; poor spark, or very late spark.

Fuel: Mixture too lean or too rich.

¹ Often occurs just after starting, due to first charges not firing in cylinder and passing through into exhaust pipe, where burning gases from first few explosions will ignite them.

Overheating

Ignition: Spark too late, or very weak.

Fuel: Mixture too rich.

Motor: Insufficient lubrication; insufficient cooling water; circulation of cooling water impeded; pump not working properly; heavy carbon deposits in cylinder; water chamber coated from impure water.

Irregular Speed

Ignition: Loose connections, or partly broken wire; vibrator points rough, pitted, or improperly adjusted.

Fuel: Supply to carburetor irregular; dirt on needle valve.

Motor: Governor gummy, sticky, out of adjustment or badly worn; valves sticky.

Smoke

Black smoke in exhaust indicates too rich a mixture. Bluish smoke indicates too much lubricating oil. Smoke from the crankcase or open end of cylinder indicates leak past the piston; look for worn rings, rings stuck in grooves, or scoring on cylinder walls.

APPENDIX

APPENDIX

PROPRIETARY BORDEAUX MIXTURES

COMMERCIAL BORDEAUX AND BORDEAUX WITH ARSENICAL PREPARATIONS *

Amounts required to furnish metallic copper and arsenic in quantities equivalent to those in a standard 4-4-50 Bordeaux with arsenical

Commercial Bordeaux.			Commercial Arsenates.		
Guaranty of Metallic Copper (Per Cent).	Amount for 50 Gals. of Spray (Pounds).	Amount for 1 Gal. of Spray (Ounces).	Guaranty of Metallic Arsenic (Per Cent).	Amount for 50 Gals. of Spray (Pounds).	Amount for 1 Gal. of Spray (Ounces).
25.0	4	$1\frac{1}{4}$	30.0	1	$\frac{1}{4}$
20.0	5	$1\frac{1}{2}$	25.0	$1\frac{1}{4}$	$\frac{1}{4}$
15.0	$6\frac{3}{4}$	$2\frac{1}{4}$	20.0	$1\frac{1}{2}$	$\frac{1}{2}$
12.5	$8\frac{1}{4}$	$2\frac{1}{2}$	17.5	$1\frac{3}{4}$	$\frac{1}{2}$
11.0	$9\frac{1}{4}$	3	15.0	2	$\frac{3}{4}$
10.0	$10\frac{1}{4}$	$3\frac{1}{4}$	12.5	$2\frac{1}{2}$	$\frac{1}{2}$
9.0	$11\frac{1}{4}$	$3\frac{3}{4}$	10.0	3	1
8.0	$12\frac{3}{4}$	4	9.0	$3\frac{1}{4}$	1
7.5	$13\frac{1}{2}$	$4\frac{1}{4}$	8.0	$3\frac{3}{4}$	1
7.0	$14\frac{1}{2}$	5	7.0	$4\frac{1}{2}$	$1\frac{1}{4}$
6.5	16	5	6.0	5	$1\frac{1}{2}$
6.0	17	$5\frac{1}{2}$	5.0	$5\frac{3}{4}$	2
5.5	$18\frac{1}{2}$	6	4.5	$6\frac{1}{2}$	2
5.0	20	$6\frac{1}{2}$	4.0	7	$2\frac{1}{2}$
4.5	$22\frac{1}{2}$	7	3.5	8	$2\frac{3}{4}$
4.0	$25\frac{1}{2}$	8	3.0	10	$3\frac{1}{4}$
3.5	29	9	2.5	12	$3\frac{3}{4}$
3.0	34	12	2.0	15	$4\frac{3}{4}$
2.5	41	13	1.5	$19\frac{1}{2}$	$6\frac{1}{4}$
2.0	51	16	1.0	29	$9\frac{1}{2}$
1.5	68	22	.5	58	19

* Adapted from Mass. Bul. 201, p. 33, 1921.

PRICES OF MATERIALS USED IN LABORATORY

Alum.....	per lb.
Ammonium hydroxide.....	per gal.
Bran.....	per lb.
Carbolic acid (crude, 95%).....	per gal.
Carbon disulphide.....	per lb.
Casein (powdered).....	per lb.
Caustic potash.....	per lb.
Caustic soda.....	per lb.
Copper carbonate.....	per lb.
Copper sulphate.....	per lb.
Corrosive sublimate.....	per lb.
Fish-oil soap.....	per lb.
Flour of sulphur.....	per lb.
Formaldehyde.....	per lb.
Glue (ground).....	per lb.
Hellebore.....	per lb.
Hydrated lime.....	per lb.
Iron sulphate.....	per lb.
Kerosene.....	per gal.
Laundry soap.....	per lb.
Lead acetate.....	per lb.
Menhaden fish oil.....	per gal.
Molasses (black strap).....	per gal.
Nicofume liquid.....	per lb.
Nicofume papers.....	per sheet
Nicotine sulphate.....	per lb.
Oleic acid.....	per gal.
Paraffin oil.....	per gal.
Paris green.....	per lb.
Petroleum (crude).....	per gal.
Potassium sulphide.....	per lb.
Pyrethrum.....	per lb.
Resin.....	per lb.
Resin fish-oil soap.....	per lb.
Resin oil.....	per gal.
Rock salt.....	per lb.
Rye flour.....	per lb.
Sal soda.....	per lb.
Sodium arsenate.....	per lb.
Sodium cyanide.....	per lb.
Stone lime.....	per lb.
Table salt.....	per lb.
Tobacco dust.....	per lb.
Tobacco stems.....	per lb.
White arsenic.....	per lb.
Zinc sulphate.....	per lb.

PRICES OF SPRAY MATERIALS

Material	Manufacturer	Price per Pound for Packages of:						
		200 Lbs.	100 Lbs.	50 Lbs.	25 Lbs.	10 Lbs.	5 Lbs.	1 Lb.
Dry Lead Arsenate								
Paste Lead Arsenate								
Dry Calcium Arsenate								
Dry Bordeaux Mixture								

PRICES OF SPRAY MATERIALS—*Continued*

Material	Manufacturer	Price per Pound for Packages of:						
		200 Lbs.	100 Lbs.	50 Lbs.	25 Lbs.	10 Lbs.	5 Lbs.	1 Lb.
Dry Bordeaux Lead								
Paste Bordeaux Lead								
Dry Zinc Bordeaux								
Dry Lime Sulphur								
B. T. S.								
Wettable Sulphur								
Para- dichloro- benzene								

PRICES OF SPRAY MATERIALS—*Continued*

Material	Manufacturer	Price per Pound for Packages of:						
		200 Lbs.	100 Lbs.	50 Lbs.	25 Lbs.	10 Lbs.	5 Lbs.	1 Lb.
85-15 Dust								
90-10 Dust								
80-10-10 Dust								
Dusting Sulphur								
Tobacco Dust								
Copper- lime Dust								
		Price per Gallon for Amounts of:						
		50 Gals.	30 Gals.	10 Gals.	5 Gals.	1 Gal.		
Lime Sulphur Solution								
Sulfocide								
Miscible Oils								

MANUFACTURERS OF SPRAY MATERIALS

Acme White Lead and Color Works, Detroit, Mich.
Alhambra Spray Co., West Alhambra, Cal.
American Horticultural Dist. Co., Martinsburg, W. Va.
Ansbacher Insecticide Co., 527 Fifth Ave., New York, N. Y.
B. G. Pratt Co., 50 Church St., New York, N. Y.
Batelle & Renwick, 80 Maiden Lane, New York, N. Y.
Bergenport Sulphur Works, 10 William St., New York, N. Y.
Bowker Insecticide Co., Boston, Mass.
Calco Chemical Co., Bound Brook, N. J.
California Central Creameries, 425 Battery St., San Francisco, Cal.
California Spray Chemical Co., Watsonville, Cal.
California Sprayer Co., Los Angeles, Cal.
Corona Chemical Co., Milwaukee, Wis.
Detroit White Lead Works, Detroit, Mich.
Devoe & Reynolds Co., 101 Fulton St., New York, N. Y.
Dosch Chemical Co., Louisville, Ky.
Dow Chemical Co., Midland, Mich.
Frost Insecticide Co., Arlington, Mass.
General Basic Products Co., 4796 E. Marginal Way, Seattle, Wash.
General Chemical Co., 25 Broad St., New York, N. Y.
Gideon Stolz Co., Salem, Ore.
Glidden Co., Cleveland, O.
Grasselli Chemical Co., Cleveland, O.
Hagerstown Sulphur Works, Hagerstown, Md.
Hall Tobacco Chemical Co., 3949 Park Ave., St. Louis, Mo.
Hood River Spray Co., Hood River, Ore.
Horticultural Chemical Co., Philadelphia, Pa.
Interstate Chemical Co., Jersey City, N. J.
James A. Blanchard Co., Hudson Terminal, N. Y.
James Good, Philadelphia, Pa.
John Lucas & Co., Philadelphia, Pa.
Latimer, Goodwin Chemical Co., Grand Junction, Col.
Leggett & Bros., New York, N. Y.
Martin Lemour Co., Chicago, Ill.
McKesson & Robbins, New York, N. Y.
Meehling Bros. Mfg. Co., Camden, N. J.
Merrimac Chemical Co., 33 Broad St., Boston, Mass.
Miller Products Co., Portland, Ore.
Niagara Sprayer Co., Middleport, N. Y.
Nichols Copper Co., 25 Broad St., New York, N. Y.
Nicotine Production Corporation, Clarksville, Tenn.
Nitrate Agencies Co., 102-4 Pearl St., New York, N. Y.
Oregon Arsenical Spray Co., Clackamas, Ore.
Parke, Davis & Co., Detroit, Mich.
Riches, Piver & Co., 30 Church St., New York, N. Y.

Sherwin-Williams Co., Cleveland, O.
Tobacco By-Products & Chemical Corp., Louisville, Ky.
Toledo Rex Spray Co., Toledo, O.
Vreeland Chemical Co., New York, N. Y.
Western Wholesale Drug Co., Los Angeles, Cal.

MANUFACTURERS OF SPRAYING EQUIPMENT

Bateman Mfg. Co., Grenloch, N. J.
Bean Spray Pump Co., Lansing, Mich.
Church, S. B., Seymont, Conn.
Cobb Mfg. Co., 60 Glen Ave., Malden, Mass.
Deming Co., Salem, O.
Douglas, W. & B., Middletown, Conn.
E. C. Brown Co., Rochester, N. Y.
Fairbanks, Morse & Co., Cleveland, O.
F. E. Meyers & Bro., Ashland, O.
Field Force Pump Co., Elmira, N. Y.
Fitzhenry-Guptill Co., 135 First St., E. Cambridge, Mass.
Friend Mfg. Co., Gasport, N. Y.
Frost Insecticide Co., Arlington, Mass.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
Hayes Pump and Planter Co., Galva, Ill.
H. B. Sherman Mfg. Co., Battle Creek, Mich.
Hudson Mfg. Co., Minneapolis, Minn.
International Harvester Co., Chicago, Ill.
Latham & Co., Sandusky, O.
Morrill & Morley Mfg. Co., Benton Harbor, Mich.
Northern Fire Apparatus Co., Minneapolis, Minn.
Pierce-Loop Co., Northeast, Pa.
Sprimotor Co., Buffalo, N. Y.
Standard Harrow Co., Utica, N. Y.
Ward-Love Pump Corp., Rockford, Ill.

MANUFACTURERS OF DUSTING EQUIPMENT

California Sprayer Co., Los Angeles, Cal.
Corona Chemical Co., Milwaukee, Wis.
Dosch Chemical Co., Louisville, Ky.
Dust Sprayer Mfg. Co., Kansas City, Mo.
Feeny Mfg. Co., Muncie, Ind.
J. H. Day Co., Cincinnati, O.
Leggett & Co., New York, N. Y.
Lloyd Manufacturing Co., Kentville, N. S.
Niagara Sprayer Co., Middleport, N. Y.
Perfect Sprayers and Dusters, Mahone Bay, N. S.
Tow Lemons Co., Springfield, Tenn.

MANUFACTURERS OF FUMIGATING MATERIALS AND EQUIPMENT

Nicotine Production Corporation, Clarksville, Tenn.

Owl Fumigating Corp., Azusa, Cal.

Pacific R. & H. Chemical Corp., Los Angeles, Cal.

Roessler & Hasslacher Chemical Co., 100 William St., New York, N. Y.

Taylor, E. R., Penn Yan, N. Y.

Tobacco By-Products & Chemical Corp., Louisville, Ky.

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